BULLETIN

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THE INSTITUTE OF PHYSICS

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47 BELGRAVE SQUARE, LONDON, S.W.1. TELEPHONE : BELGRAVIA 6111-2-3

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

SUNDERLAND EDUCATION AUTHORITY
THE TECHNICAL COLLEGE
DEPARTMENT OF PHYSICS

Applications are invited for RESEARCH STUDENTSHIPS in physics or electronics. Candidates should hold a good honours degree or equivalent qualification. Undergraduates in their final year will be considered. In the first instance, successful candidates will be appointed for two years, and will be expected to work for higher degrees. The annual value of each Studentship is £500.
Further particulars and forms of application may be obtained from the Registrar, Technical College, Sunderland, Co. Durham. Applications should be sent to the undersigned as soon as possible. W. Thompson, Director of Education, Education Offices, 15 John Street, Sunderland, Co. Durham.

PHYSICISTS required preferably with at least honours degree for fundamental and applied industrial research. Write for form of application to Controller of Research, The British Plaster Board (Holdings) Ltd., East Leake, Nr. Loughborough, Leics., quoting 508/KS/BIP.

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR
DEPARTMENT OF ELECTRONIC ENGINEERING

Applications are invited for the following posts :—
(*a*) SENIOR LECTURER OR LECTURER IN CONTROL ENGINEERING. Applicants should have research or industrial experience with servomechanisms or in process control.

(*b*) LECTURER IN MATERIALS. Applicants should have a thorough knowledge of the physics of materials and should preferably have had research or industrial experience involving solid state physics.

(*c*) LECTURER IN ELECTRONIC ENGINEERING. Applicants should have good qualifications in light current electrical engineering or in physics. The salary scale for a Senior Lecturer is £1,650 × £75 – £2,050 p.a. and for a Lecturer is £900 × £50 – £1,350 × £75 – £1,650. The initial salary will depend on the qualifications and experience of the person appointed. In addition there are F.S.S.U. benefits and family allowances. The appointments will date from September 1, 1959, or from dates to be arranged with the successful candidate. Two copies of the application should reach the undersigned, from whom further particulars may be obtained, not later than June 20, 1959.
Kenneth Lawrence, Secretary and Registrar.

ENGLISH ELECTRIC VALVE COMPANY LTD.

A senior position exists with the Semi-conductor Department of the Company's Works at Chelmsford for a qualified and experienced

PHYSICIST

to lead a group on the further development of silicon and germanium high-power rectifiers.

Experience in this field and a good honours degree or higher qualification are required.

Age should be between 28 - 35 years.

There are other less senior positions to be created within this department and applications for these are invited from men with honours degrees and experience in industry of the development, design or production of semi-conductor devices.

Please write giving full details to Dept. C.P.S., Marconi House, 336/7 Strand, W.C.2., quoting reference PB 1502E.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH : PRINCIPAL SCIENTIFIC OFFICERS. Three pensionable posts at National Engineering Laboratory, East Kilbride, Glasgow, for men or women viz : (*a*) PHYSICAL METALLURGIST to be responsible for metallurgical aspects of research on plasticity over a wide field from metal physics through properties of materials to investigation of formation and cutting processes such as extrusion and machining ; (*b*) ENGINEER OR PHYSICIST to take charge of fundamental research on cutting ; (*c*) ENGINEER interested in hydrodynamic lubrication to lead research on dynamically loaded bearings and factors governing bearing instability. Qualifications normally first or second class honours degree in scientific subject (including engineering), or high professional attainment. Appropriate research experience essential. Industrial experience an advantage. Salary scale (men) £1,420 – £2,020. Starting pay may be above minimum. Good housing prospects. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application form, quoting S4986/59/9.
Closing date June 25, 1959.

ROYAL TECHNICAL COLLEGE, SALFORD

Applications are invited from suitable candidates for the post of HEAD OF DEPARTMENT of Pure and Applied Physics which will become vacant on January 1, 1960. This is a Grade V department carrying a salary of £1,995 × £52 10s. – £2,152 10s.
The department is recognized for the award of a Diploma in Technology in Applied Physics and has an active research school.
Further particulars and forms of application can be obtained from the Registrar, Royal Technical College, Salford 5, Lancs., to whom completed applications should be returned not later than July 1, 1959. R. Ribblesdale Thornton, Clerk to the Governors.

RESEARCH PHYSICISTS

Courtaulds invites applications for two graduate physicists to carry out original work in the field of classical physics entailing the development of electronic and other apparatus. Research experience is not essential as there are first class training facilities within the organization. The vacancies are in Coventry. Age should not exceed 26 and only candidates with good Honours degrees can be considered. The appointments are pensionable and the occupants will be eligible for co-partnership benefits.
Candidates should write for a detailed form of application to the Director of Personnel, Courtaulds Limited, 16 St. Martin's-le-Grand, London, E.C.1, quoting reference number D.95.

PORTSMOUTH
COLLEGE OF TECHNOLOGY
PHYSICS AND MATHEMATICS DEPARTMENT

Applications are invited immediately for the post of Head of this Department (Grade IV)—Salary Scale £1,837 10s.–£52 10s.–£1,995, to commence duties on January 1, 1960. Applicants should possess high academic qualifications, and have had experience of full-time teaching, together with industrial and/or research experience. The Department is recognized by the Institute of Physics. The person appointed will be expected to develop further the already substantial volume of advanced work and to foster research work. Forms of application and further information available from the Registrar of the College.

British Petroleum has a vacancy for a PHYSICIST with an Honours degree for work at its research station at Sunbury-on-Thames, Middlesex. Successful applicant will join a group studying the fundamentals and the practical application of filtration and the separation of water from oil fuels. Age, under 35. Salary according to age, qualifications, and experience. Non-contributory pension fund. Assisted house purchase scheme. Removal expenses and settling-in allowance payable in certain cases. Luncheon club. Write giving full particulars, quoting reference H.4454, to the Manager, Recruitment Branch, The British Petroleum Company Limited, BP House, Ropemaker Street, London, E.C.2.

RESEARCH PHYSICIST

Research Physicist required for research and development work in the Research Laboratory of a company engaged in the development and production of a wide variety of components used by the electronic industry. Well equipped laboratories exist and a large program of basic research and interesting development work is in hand. Applicants, who should have a degree or similar qualification, with research experience in any field of modern industry are invited to apply to ascertain whether they have a part to play in work which offers scope and excellent prospects. An invitation to inspect the laboratories, to ascertain the amenities provided and to discuss salary will be extended to selected candidates who forward full details of their career to the Personnel Manager, Welwyn Electrical Laboratories Ltd., Bedlington, Northumberland

THE GENERAL ELECTRIC COMPANY LIMITED

Owing to the continued expansion of the Company's activities in the civil nuclear field both in the United Kingdom and recently in Japan, additional staff is required in the Reactor Heat Transfer Section.

The Section is part of the Research and Development Department and is concerned with the following activities :—

(*a*) Design and improvement of reactor fuel elements of present and future types.

(*b*) Evaluation of temperature profiles within reactor structures, pressure vessels and other equipment.

(*c*) Solution of novel problems of gas kinetics associated both with reactor cores and with charge-discharge mechanisms.

Extensive laboratory facilities are available and applicants who are keen on experimental work will find ready co-operation from existing laboratory technicians. A digital computer is available for the numerical solution of theoretical work and for data reduction. **The following staff are required :—**

1. **Senior graduates preferably with higher degrees in heat transfer or with several years research or development experience.**

2. **Graduates in mechanical or chemical engineering, physics or applied mathematics both for theoretical and experimental work.**

3. **Engineers with H.N.C. or H.N.D. with experience in experimental work.**

Applications which will be treated as confidential, should be made in writing giving details of experience to Personnel Manager (DWB/5), The General Electric Company Limited, Erith, Kent.

CENTRAL ELECTRICITY
GENERATING BOARD
RESEARCH LABORATORIES, LEATHERHEAD, SURREY

ENGINEERS AND PHYSICISTS (Ref. PB/137) required in the Generation Section, for work on heat transfer problems associated with the fuel elements for nuclear power stations. The work is principally carried out on large test rigs, but in addition, investigations would be made into the temperature drop at the interface between the fuel and its protective sheath. Applicants should have an honours degree and previous research experience is desirable.

Salaries on scales within the ranges £1,195 – £1,775 or £570 – £1,300 p.a. according to duties and responsibilities.

ENGINEER OR PHYSICIST (Ref. PB/143) required in the Generation Section, to take charge of a small team working on basic research into the mechanism of mechanical seals for use in large boiler feed-pumps and high pressure gas circulators.

Applicants should possess an honours degree and have a sound knowledge of fluid dynamics. Previous research experience is essential although this need not necessarily have been in this particular field.

Salary scale within the range £1,195 – £1,775 according to duties and responsibilities.

Application forms obtainable from, and returnable to, the Personnel Officer, 24-30 Holborn, London, E.C.1, by June 30, 1959. Please mark envelopes "Confidential" quoting relevant reference number.

COUNTY BOROUGH OF
ROTHERHAM
EDUCATION COMMITTEE
COLLEGE OF TECHNOLOGY
DEPARTMENT OF METALLURGY AND CHEMISTRY

Applications are invited for appointment as ASSISTANT INVESTIGATOR in connection with a special program of research in powder metallurgy which is to be carried out in the above department with the support of the department of scientific and industrial research.

The college is a specialist centre for powder metallurgy and the department has done much pioneer work in this field during the recent years.

The appointment will be for a period of three years at a salary of £750 to £800 per annum, and the work will be carried out under the directions of Mr. D. Yarnton, B.Sc., F.I.M., Senior Lecturer in Metallurgy.

Previous experience of powder metallurgy is not necessary but candidates should have a sound knowledge of physical metallurgy.

Further details may be obtained from the undersigned, to whom applications (no form provided) stating the names of at least two referees should be sent before the end of June. R. Bloomer, Director of Education, Education Office, 21 Moorgate, Rotherham.

Supplement to the BULLETIN *of The Institute of Physics, June, 1959*

Physics Courses in Colleges of Technology

This supplement contains announcements of physics courses and special lectures that will be available during the 1959-60 session in some of the principal Colleges of Technology. It is hoped that this will be of use to students, to young graduates wishing to know of postgraduate lectures and to senior members of the Institute concerned with the training of assistants.

BATTERSEA COLLEGE OF TECHNOLOGY
LONDON, S.W.11

Department of Physics and Section of Crystallography

Undergraduate Courses

1. B.Sc. Special (University of London Internal). Full-time and part-time courses.
2. Diploma in Technology. This course is arranged on a Thick Sandwich basis suitable for both College and Industry based students. It consists of three years in College with an industrial year between the second and third College years. It is recognized for exemption from the Graduateship of The Institute of Physics.

Postgraduate Courses

1. Microwave Physics.
2. X-ray Crystallography.

These courses consist of lectures and practical work and can be taken either full-time or part-time. Suitably qualified students may proceed to the M.Sc. (London Internal) by dissertation and/or examination or to the Postgraduate Diploma of the College.

3. Industrial Radiation Hazards and Protection (part-time).

Research

There are vacancies for students to do research leading to the M.Sc. or Ph.D. (London Internal) in the following fields:

1. Microwave Physics
2. Metal Physics
3. Rheology
4. Theoretical Nuclear Physics
5. Crystallography

A small number of Research Assistantships is available for suitably qualified students.

All enquiries should be addressed to
L. R. B. Elton, Ph.D., F.Inst.P., Head of the Physics Department.

CITY OF PORTSMOUTH COLLEGE OF TECHNOLOGY

Principal : W. TAYLOR, D.Sc.(Lond.), F.R.I.C.

DEPARTMENT OF PHYSICS AND MATHEMATICS

Head : H. HARLE, M.Sc.(Lond.), A.R.C.S., D.I.C., F.Inst.P.

A FULL-TIME THREE-YEAR COURSE FOR THE EXTERNAL B.Sc. GENERAL DEGREE (REVISED REGULATIONS) OF LONDON UNIVERSITY

A PART-TIME DAY AND EVENING COURSE IS ALSO AVAILABLE

Full particulars of these and other courses in physics and mathematics may be obtained from the Head of the Department.

BOROUGH POLYTECHNIC

BOROUGH ROAD, S.E.1

The following undergraduate courses in Physics are available:—

Sandwich Course (four years)
leading to the
DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS
(*with specialization in Applied Nuclear Physics*)

Part-time (Day or Evening) Courses
leading to the
GRADUATESHIP OF THE INSTITUTE OF PHYSICS

Part-time (Day or Evening) Courses
in preparation for
SCIENCE DEGREES
(*External*)
of the University of London

For Prospectus of (*a*) Full-time and Sandwich courses or (*b*) Part-time courses, apply to the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

BOROUGH POLYTECHNIC

BOROUGH ROAD, S.E.1

Special Postgraduate Courses in Applied Physics

SESSION 1959/60

Lecture Courses, by specialist lecturers, will be held weekly in the evening (also in the afternoon, where asterisked)

Title	*No. of Lectures*	*Commencing date*
Electronics at Low Temperatures	12	2nd October
*Nuclear Power	24	8th October
Nucleonic Circuitry (Electronic Equipment used in Nuclear Physics)	10	7th October
Nuclear Particle Techniques (Nuclear Instruments and isotope applications)	16	13th January
Reactor Instrumentation and Control	6	28th April
Digital Circuit Techniques	12	2nd October
*Principles and Applications of Transistors	20	6th October
Principles of Pulse Techniques	22	12th October

Laboratory Courses will also be held weekly in the following subjects:

Nucleonic Techniques and Measurements
(Eight-week full-time courses are also available in this subject)

Basic Transistor Measurements

Pulse Circuits and Techniques

Transistor Pulse Circuits

A two-week, full-time course will also be held on the
Design, Use and Maintenance of Electronic Equipment used in Nuclear Physics

Leaflets giving full particulars of these and of other postgraduate courses can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

COLLEGE OF TECHNOLOGY

BIRMINGHAM, 4

Telephone: Aston Cross 3611

Principal: P. F. R. VENABLES, Ph.D., B.Sc., F.R.I.C.

DEPARTMENT OF PHYSICS

Head of Department: J. H. DAVIS, Ph.D., B.Sc., F.Inst.P., A.M.I.E.E.

SESSION 1959-60

FULL-TIME COURSES	B.Sc. General Degree (London) (External) B.Sc. Special Degree (London) (External) Diploma in Technology Sandwich Course in Applied Physics Ophthalmic Optics Nuclear Power Technology (Six weeks course)
PART-TIME DAY AND EVENING COURSES	Higher National Certificate in Applied Physics Graduateship of The Institute of Physics B.Sc. General (London) (External) B.Sc. Special (London) (External) Associateship of the College
EVENING COURSES	Postgraduate Courses in:— Transistors, Wave Guides and Centimetric Waves, Electronics, Fluctuations, Vacuum Technique, Acoustics and Noise Measurement, X-rays, Ophthalmic Optics Nuclear Power Technology.

SESSION OPENS ON SEPTEMBER 28th, 1959

Further particulars and forms of application for the full-time courses and details of other courses are given in the prospectus and may be obtained from the Head of Department of Physics.

COLLEGE OF TECHNOLOGY, OXFORD

SCHOOL OF SCIENCE

Full-time courses for

The Graduateship Examinations of The Institute of Physics and The Royal Institute of Chemistry
University of London External General B.Sc.
General Certificate of Education at Advanced Level

Part-time day and evening courses for

The Ordinary and Higher National Certificate in Applied Physics, Chemistry, Metallurgy and the Endorsed Certificate in Biology
The Licentiateship Examination of The Institution of Metallurgists
The Graduateship Examination of The Institute of Physics and The Royal Institute of Chemistry

Full particulars from The Principal, College of Technology, Headington Road, Oxford Tel. No. Oxford 63434

THE POLYTECHNIC

309 Regent Street, W.1

DEPARTMENT OF MATHEMATICS AND PHYSICS

Full-time and part-time day courses are available for B.Sc. General in Pure Mathematics, Physics and Chemistry (Part I), Physics and Mathematics or Chemistry (Part II), B.Sc. Special in Physics and Grad. Inst.P.

Evening courses are offered in B.Sc. General, Statistics, Electronics, and Postgraduate Mathematics.

Prospectuses may be obtained from the Director of Education.

BRISTOL COLLEGE OF TECHNOLOGY

Part-time day and evening courses are offered for the following qualifications:

ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

B.Sc. (GENERAL) NEW REGULATIONS

Further details may be obtained from the Registrar, College of Technology, Ashley Down, Bristol, 7.

SOUTH EAST LONDON TECHNICAL COLLEGE

LEWISHAM WAY, S.E.4

Telephone TID 1421/3

Courses in Applied Physics

Evening courses and part-time day courses for the following:

ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

SANDWICH COURSES

Two and four-year courses on electronics, instrument technology and telecommunications.

Postgraduate evening courses on specialized Physics topics.

Further details from the Head of the Department of Electrical Engineering and Applied Physics. (627).

Middlesex County Council Education Committee

BRUNEL COLLEGE OF TECHNOLOGY

Woodlands Avenue, Acton, W.3

DEPARTMENT OF MATHEMATICS

EVENING LECTURES for the SESSION 1959-60

MATHEMATICS AND TECHNIQUES OF CIRCUIT ANALYSIS
(jointly with Department of Electronics)
by C. C. Ritchie, M.A., and C. J. Wayman, B.Sc.(Eng.)

COMPLEX VARIABLE, LAPLACE TRANSFORMATION AND CONTROL SYSTEMS
by H. Goldenberg, M.Sc.

DEFORMATION AND FLOW OF HIGH POLYMER SUBSTANCES
by R. W. Whorlow, B.Sc.

FINITE DIFFERENCE EQUATIONS
by H. Levy, M.A., D.Sc., F.R.S.E.

ENGINE AERODYNAMICS
(jointly with Department of Mechanical Engineering)
by A. W. Morley, Ph.D.

PROGRAMMING THE I B M 650
by J. A. C. King, B.Sc.

THEORY OF QUEUEING AND INDUSTRIAL APPLICATIONS
by F. Gordon Foster, Ph.D., followed by a panel of experts from industry.

MODERN COMPUTING METHODS
by A. R. Curtis, M.A., E. T. Goodwin, M.A., Ph.D., J. H. Wilkinson, M.A.

INDUSTRIAL STATISTICS
(i) Design and interpretation of experiment
(ii) Analysis and presentation of data
by Miss J. Keen, B.Sc., D. J. Farlie, B.Sc., and A. N. James, B.Sc.

VECTOR ANALYSIS
by G. D. Smith, M.Sc.

DIFFERENTIAL EQUATIONS
by G. D. Smith, M.Sc.

A3 MATHEMATICS FOR MECHANICAL ENGINEERS

Further details may be obtained from the Head of the Mathematics Department.

C. E. GURR, M.Sc., Ph.D., *Clerk to the Governing Body.*

ROYAL TECHNICAL COLLEGE, SALFORD

DEPARTMENT OF PURE AND APPLIED PHYSICS

Head of Department: W. G. DARVELL, M.Sc., F.Inst.P.

FULL-TIME COURSES	General B.Sc. (New Regulations). Applied Physics—Sandwich Course leading to Diploma in Technology. Nuclear Energy (6 weeks). Dates to be arranged.
PART-TIME DAY AND EVENING COURSES	Special and General B.Sc., Higher National Certificate. Grad.Inst.P. (Physics I, II, III, More Advanced Physics, Electronics, X-rays, Nuclear Instruments).
EVENING COURSES	Postgraduate lectures, including— *Autumn Term*—Magnetism and Magnetic Materials *Spring Term*—High Vacua in Research and Industry
RESEARCH	Details of facilities for research and projects being studied will be sent on request.

Complete details of these and other courses may be obtained from the Head of Department

R. RIBBLESDALE THORNTON, *Clerk to the Governors.*

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY

WOODLANDS AVENUE, ACTON, W.3

Principal: J. TOPPING, M.Sc., Ph.D., D.I.C., F.Inst.P.

The following courses are among those to be held during the session 1959-60. Autumn term begins September 21st, 1959.

DEPARTMENT OF PHYSICS

Head of Department: C. A. HOGARTH, B.Sc., Ph.D., F.Inst.P.

DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS

A four-year Sandwich course commencing in January, 1960. Specialist subjects in the course include Nuclear Technology, X-ray Crystallography, Electronics, High Vacuum Technology, Electrical and Magnetic Properties of Solids, Applied Acoustics.

B.Sc.(GENERAL) DEGREE OF THE UNIVERSITY OF LONDON

The next part-time course begins in September, 1959, and extends over four years.

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

Subjects include Electronics, High Vacuum Technology, Illumination, Applied Acoustics. New course begins in September, 1959, and is held on a day-release basis.

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

A day-release course for holders of the Higher National Certificate in Applied Physics commencing in September, 1959, and extending over two years.

Evening courses to postgraduate standard are offered in the following subjects: Non-destructive Testing, X-ray Crystallography, High Vacuum Technology, Ultrasonics, Recent Advances in Physics.

DEPARTMENT OF MATHEMATICS

Head of Department: J. CRANK, M.Sc., D.Sc., F.Inst.P.

DIPLOMA IN TECHNOLOGY IN MATHEMATICS

A four-year Sandwich course commencing in September, 1959. Modern Applied Mathematics, practical computation and Statistics are supported by relevant sections of Pure Mathematics, Physics and Electronics. The course is open to employees of firms willing to support them, and also to school leavers. State Scholarships and Local Education Awards may be held by students attending this course.

Full details of courses and enrolment forms obtainable from the Registrar. (ACOrn 6661).

C. E. GURR, M.Sc., Ph.D., *Clerk to the Governing Body*

County Borough of Brighton Education Committee

BRIGHTON TECHNICAL COLLEGE

Principal: G. E. WATTS, M.A., Ph.D.(Cantab.), B.Sc.(Lond.), F.R.I.C.

Head of Physics Department: N. PENTLAND, M.Sc., Ph.D.(Lond.), F.Inst.P.

Enquiries are invited from prospective students, or employers of prospective students, in connection with the following courses which will be in operation during the session 1959/60:

(*a*) **4-year Sandwich Diploma in Technology Course in Applied Physics**—College sessions of the course commence in January each year. Successful students will be given exemption from the academic requirements for Graduateship of The Institute of Physics.

(*b*) **3-year Full-time College Diploma Course in Applied Physics**—September entry. Successful students will be given exemption from the academic requirements for Graduateship of The Institute of Physics.

(*c*) **Ordinary and Higher National Certificate Courses in Applied Physics,** including Conversion Year between G.C.E. Advanced Level and Higher National Certificate.

(*d*) **Graduateship of The Institute of Physics**—a 2-year day release course for holders of the Higher National Certificate in Applied Physics.

Further details and enrolment forms from the Registrar, Brighton Technical College, Brighton 7.

W. G. STONE, M.A., *Director of Education.*

WELSH COLLEGE OF ADVANCED TECHNOLOGY

CATHAYS PARK, CARDIFF

Principal : A. HARVEY, Ph.D., B.Sc., F.Inst.P.

Diploma in Technology in Applied Physics

A four-year Sandwich course in Applied Physics leading to the Diploma in Technology (Dip. Tech.) will commence in September, 1959.

This Diploma will be a qualification satisfying completely the academic requirements for Graduateship and corporate membership of The Institute of Physics.

Students may be " works " or " College " based, and will spend alternate six-monthly periods in College and Industry.

Normal requirements for admission to the course will be success at G.C.E. " A " level, or O.N.C., at a high standard, in Applied Physics or Electrical Engineering.

Details of the course may be obtained from, and applications should be made to, the Principal.

ROBERT E. PRESTWOOD,
Clerk to the Governors.

City Hall, Cardiff.

BRADFORD INSTITUTE OF TECHNOLOGY

Principal: E. G. EDWARDS, B.Sc., Ph.D., F.R.I.C.

DEPARTMENT OF PHYSICS

Head of Department: D. L. SMARE, B.Sc., M.Sc.(Tech.), Ph.D., F.Inst.P.

SESSION 1959-60

Full-time courses of study will be available in the following subjects:

Applied Physics. A four-year Sandwich course leading to the qualification of Dip. Tech. Students will spend alternate periods of six months in College and in industry and may be either "industry" or "College" based.

B.Sc. London External. Three-year courses for the General Degree (two final subjects selected from Physics, Chemistry, Mathematics, Botany or Zoology).

Nuclear Reactor Technology (in collaboration with the Department of Electrical Engineering). Six weeks duration: the next course will begin on August 31st and others will be arranged later in the session.

Ophthalmic Optics. A three-year course leading to a recognized professional qualification.

Special Short Courses are being arranged in Nuclear Physics, Physics of the Solid State, Illumination, X-ray and γ-ray Radiography, Optical measuring devices, Ophthalmic Optics.

Further details and forms of application for these courses may be obtained from the Head of Department.

KINGSTON TECHNICAL COLLEGE

FASSETT ROAD, KINGSTON-ON-THAMES

Department of Physics and Mathematics

offers full-time and part-time courses for

B.Sc. GENERAL DEGREE

ORDINARY AND HIGHER NATIONAL CERTIFICATES IN APPLIED PHYSICS

POSTGRADUATE COURSES in Electronics and acoustics.

Further particulars from the Head of Department

Huddersfield College of Technology

Principal:
W. E. SCOTT, M.B.E.

Department of Physics

Twelve lectures on "Semi-Conductors and their Applications"

Wednesdays, 7-9 p.m., beginning 23rd September 1959. Course fee 30s.

The course will include an outline of the theory of semi-conductors, and an account of the preparation of semi-conducting materials and of rectification properties and the application of semi-conductor rectifiers.

The design, manufacture and application of transistors will also be included. Special purpose devices will be described.

Further details may be obtained from the Registrar.

H. GRAY,
Chief Education Officer.

SIR JOHN CASS COLLEGE

Jewry Street, Aldgate, E.C.3.

The College provides Full-time and Part-time (Day Release) Courses for the Internal Special Degree in Physics and the B.Sc. (General) Degree (Revised Regulations) of the University of London.

There are also courses for the Graduateship Examination of the Institute and special courses of lectures on various topics including Meteorology and Quantum Mechanics.

Research work for a higher degree in Physics may also be undertaken, full-time or part-time.

Prospectus, application forms and details of special courses may be obtained from the Secretary.

CHELSEA COLLEGE OF SCIENCE AND TECHNOLOGY

Session 1959-60

Department of Physics Postgraduate courses, full and part-time

The following courses begin on 5th October, 1959 :

ACOUSTICS AND VIBRATION PHYSICS	SEMICONDUCTORS
OPTICS	ELECTROMAGNETISM
NUCLEAR PHYSICS	PHYSICAL ELECTRONICS
QUANTUM MECHANICS	ELECTRONIC CIRCUITS

Suitably qualified students may register as M.Sc. Internal students of the University of London.

DEGREE COURSES, full-time and " Sandwich."

The following courses begin on 28th September, 1959 :

Full-time and " Sandwich " courses for Special degree.

Full-time courses for General degree.

For students engaged in industry, the *sandwich* course has been planned as an alternative part-time course in which students attend for two terms full-time and one term part-time in each of four sessions. Each course is an Honours course and students study as Internal students of the University of London.

Details and application forms may be obtained from : The Secretary, Physics Dept., Chelsea College of Science and Technology, London, S.W.3. FLAxman 5747

GLAMORGAN EDUCATION COMMITTEE

GLAMORGAN COLLEGE OF TECHNOLOGY

TREFOREST, PONTYPRIDD, GLAM.

Principal : D. P. EVANS, M.Sc., Ph.D., F.R.I.C., M.B.I.M.

Department of Physics and Mathematics

A four year Sandwich Course, established in 1954, is open to either Works-based or College-based students and leads to the Associateship of the College in Applied Physics, and to the Graduateship of The Institute of Physics.

Candidates for admission must possess appropriate " A " level G.C.E. subjects or a good O.N.C. in either Applied Physics or Electrical Engineering.

Further details and enrolment forms may be obtained from the Principal.

E. STEPHENS, M.Sc., Ph.D.,

Director of Education.

Northampton College of Advanced Technology, London

SESSION 1959-60

Applied Physics Sandwich Course for the Diploma in Technology

This course was started in January, 1956, the award being a College Diploma recognized by The Institute of Physics as carrying exemption from the Graduateship examination. It has now been approved for the Diploma in Technology.

The scheme is a co-operative enterprise to which the College and the Industrial Organization contribute equally. It provides a training in theoretical and experimental physics, with particular emphasis on the application of physics in industry.

The duration of the course is four years ; in each year the student spends an average of six months in full-time study at the College and the remainder in practical training with his employer. The College appoints a tutor to the students of each firm. In addition to supervising their progress while in College, the tutor visits the students during their industrial periods and acts as a liaison officer with the firm.

The technical subjects in the course consist of Physics, Applied Physics and Mathematics, together with ancillary subjects. In the Applied Physics of the final year the student selects two subjects in which to specialize; he also undertakes a project related to his particular field of study. In addition, a proportion of the time is spent in non-technical studies.

All students become members of the Students' Union Society and are expected to share in its activities, which include a recently-formed Physical Society.

In view of the increasing support from industry and to assist some industrial training programmes, it has been decided to arrange two courses each year. The First Year courses starting in 1959-60 will be as follows:

(1) Tuesday, September 1st, 1959, to Friday, February 12th, 1960.

(2) Monday, February 15th, 1960, to Friday, July 29th, 1960.

Part-time Postgraduate Courses

The following courses will be conducted during the session:

SEMI-CONDUCTORS
AN INTRODUCTION TO NUCLEAR POWER
OPTICAL INSTRUMENTS
PHOTO-ELASTICITY
APPLIED ACOUSTICS
HIGH VACUUM TECHNIQUE
ELECTRON MICROSCOPY
NON-DESTRUCTIVE TESTING
MAGNETIC MATERIALS

Further details of the above courses may be obtained from the Head of the Applied Physics Department, Northampton College, St. John Street, London, E.C.1

NORTHERN POLYTECHNIC

HOLLOWAY, N.7 **NORth 1686**

Department of Physics Session 1959-60

DEGREE COURSES OF PHYSICS for Internal Degrees of The University of London.

FULL-TIME AND PART-TIME COURSES leading to
B.Sc. Special Physics
B.Sc. General
M.Sc. by examination
Research leading to Ph.D., and M.Sc.

SANDWICH COURSE leading to B.Sc. Special Physics.

ADVANCED PART-TIME COURSES in
Electrical Discharges in Gases
Solid State Physics

Students with suitable degrees in Physics, following one of these courses, accompanied by practical work, can proceed to the M.Sc. degree of the University of London.

The lectures are not confined to such students, but are open to any working in appropriate fields.

COURSES IN APPLIED PHYSICS

DIPLOMA COURSE IN THE PHYSICS AND TECHNOLOGY OF ELECTRONICS

Sandwich Course leading to the Diploma in Technology (Dip. Tech.) and Graduateship of The Institute of Physics (Grad.Inst.P.)

Part-time Course leading to Graduateship of The Institute of Physics

NATIONAL CERTIFICATES IN APPLIED PHYSICS

Ordinary National Certificate. Course available to Students of 16 and over.

Higher National Certificate. Course available to students with O.N.C. or with suitable passes in G.C.E.

Students taking the H.N.C. Course at the Northern Polytechnic can proceed to complete the College Diploma Course and qualify in this way for Grad.Inst.P.

Inquiries should be addressed to The Head of the Department of Physics.

Essex Education Committee

SOUTH-EAST ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

Longbridge Road, Dagenham, Essex

Principal: F. HEATHCOAT, M.Sc., Ph.D., F.R.I.C., F.I.M.

PHYSICS AND MATHEMATICS DEPARTMENT

Head of Department: H. S. BARLOW, M.Sc., F.Inst.P., F.I.E.S.

1. Full-time, part-time day and evening courses are provided for the B.Sc. General Degree, Graduateship of The Institute of Physics and General Certificate of Education (Advanced Level).

2. Part-time day and evening courses are provided for the Ordinary National Certificate in Applied Physics, Higher National Certificate in Electrical Engineering (Light current), C.G.L.I. courses in Radio and Telecommunications Engineering and C.G.L.I. and I.B.P. Courses in Photography (Scientific).

3. Special evening courses to post graduate standard are provided in Experimental Physics, Advanced Electrical Circuit Theory, Servomechanisms and Process Control, Non-destructive Testing, Microwave Principles and Practice, Statistics and Numerical Analysis.

Further particulars of courses may be had on application to the Head of Department.

WEST HAM COLLEGE OF TECHNOLOGY

STRATFORD, E.15

Department of Physics and Mathematics

For particulars of Full and Part-time Courses in Physics, Mathematics, Electrical Engineering in preparation for the London Internal B.Sc. Degree and other Professional Examinations, apply to the Principal.

Facilities for research leading to Higher Degrees are available.

BOURNEMOUTH MUNICIPAL COLLEGE OF TECHNOLOGY AND COMMERCE

Part-time day and evening courses are offered for the following qualifications :—

ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

Full-time and part-time courses are also available for:

B.Sc. (GENERAL) NEW REGULATIONS

Full details may be obtained from the Head of the Science Department, Dr. C. J. Cooper, B.Sc., A.R.C.S., F.R.I.C., Bournemouth Municipal College of Technology and Commerce, Lansdowne, Bournemouth.

THE COLLEGE OF AERONAUTICS

One Year Postgraduateship Course in Control Engineering 1959-60

Applications are invited for the one year course in Control Engineering which begins on 5th October, 1959. Prospective students must be of graduate status in an appropriate branch of science or engineering and, preferably, have had practical experience in industry or an establishment.

The purpose of the course is to give instruction in the techniques employed in control engineering as applied in a wide range of industries. Students wishing to do so may specialize in the applications of control engineering to aeronautics.

One Year Postgraduateship Course in Fluid Mechanics 1959-60

A one year postgraduate course in "Fluid Mechanics" will be held at the College during the Autumn, Spring and Summer terms of the academic year 1959-60.

The course is intended for students wishing to acquire a knowledge of fluid mechanics at an advanced level without necessarily specializing in aeronautics. Applicants must be graduates in a branch of science or engineering and have had practical experience in one of the subjects covered by the course.

The content of the course includes the general theory of fluid flow at subsonic, supersonic and hypersonic speeds, high temperature gas dynamics and hydromagnetics, project work, experimental facilities and techniques and specialized aspects of ship hydrodynamics (including cavity flows, behaviour of ships at sea and high-powered ship propulsion) and mathematics.

Further information and forms of application for both the above courses may be obtained from the Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks.

CROYDON TECHNICAL COLLEGE

Principal:
H. FALKNER,
M.Sc. (Wales), B.Sc. (Lond.), A.Inst.P.

DEPARTMENT OF SCIENCE

Part-time day and evening courses are offered for the following qualifications :-

B.Sc. (General) - New Regulations

Graduateship of The Institute of Physics

Higher National Cert. in Applied Physics

Ordinary National Cert. in Applied Physics

Further particulars and information may be obtained from the Head of the Science Department, Croydon Technical College, Fairfield, Croydon.

North Stafford Technical College, Stoke-on-Trent

Principal: E. R. PATRICK, Ph.D., B.Eng., A.M.I.Mech.E., A.M.I.E.E.
Head of Department: A. G. PEACE, B.Sc., Ph.D., F.Inst.P.

PHYSICS DEPARTMENT—SESSION 1959-60

POSTGRADUATE COURSES IN APPLIED PHYSICS

1. **Nuclear Physics**—commencing October 1959.
   An evening course of about 20 weekly lectures dealing with the physics of radioactive materials and their applications, and including reactor physics.
   Course fee: £2 2s. 0d.
2. **Solid State Physics**—commencing January 1960.
   A course of 10 weekly lectures dealing with the theories of the structure and properties of solid materials, of interest to metallurgists, physicists, etc.
   Course fee: £1 1s. 0d.
3. **Computers**—commencing April 1960.
   A general review of the technical development and operation of both digital and analogue computers.
   Course fee: £1 1s. 0d.

Regular Courses in Applied Physics

The department provides instruction in Physics at Higher National Certificate and degree level to students of the departments of Engineering, Ceramics, Chemistry and Mining. It also provides courses for Ordinary and Higher National Certificates in Applied Physics, and for City and Guilds and short specialist courses in Industrial Instrumentation.

Full details of the above and other courses offered may be obtained from the Head of the Department.

Sunderland Education Authority

SUNDERLAND TECHNICAL COLLEGE

SESSION 1959-60

COURSES IN PURE AND APPLIED PHYSICS

1. **Diploma in Technology—Applied Physics**
   A four-year "Sandwich" course in Applied Physics for the Diploma in Technology will commence in October, 1959. The course will provide a balanced training for the industrial physicist and give exemption from the academic requirements of The Institute of Physics for Graduateship and corporate membership.
2. **B.Sc. Pure Science**
   A three-year full-time course for the external B.Sc. General Degree of London University is offered in the subjects of Physics, Chemistry and Mathematics.
3. **Higher National Certificate in Applied Physics**
   Part-time day and evening courses are provided for the Higher National Certificate in Applied Physics.
4. **Graduateship of The Institute of Physics**
   Part-time classes are provided for holders of
   (*a*) a Higher National Certificate in Applied Physics, and
   (*b*) a pass B.Sc. in the subjects Physics, Mathematics, More Advanced Physics and Electronics to enable them to qualify for Graduate membership of the Institute.
5. **Short Courses**
   (*a*) Electrical breakdown in gases. Four lectures commencing Thursday, November 5th, 1959.
   (*b*) Semi-conductors. Six lectures commencing Monday, February 1st, 1960.

Further details of these courses may be obtained from the Registrar, Technical College, Sunderland.

W. THOMPSON, *Director of Education.*

THE INSTITUTE OF PHYSICS

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The New Particles*

By Professor O. R. FRISCH, O.B.E., M.A. D.Sc., F.R.S.

(*Jacksonian Professor of Natural Philosophy, University of Cambridge*)

FORTY years ago the world was thought to be made of three fundamental particles: the proton, the electron and the photon. To-day we have thirty (most of them unstable and very rare). Perhaps there are still more to come; but no new ones (only such as were expected) have been found in the last five years. If there are others—there are some unconfirmed reports—they must be much rarer or more elusive.

Of those thirty we know a good deal: their masses, charges, spins, parities, transformation properties, collision cross-sections, etc. They are so many clues to the crossword puzzle; but we are not sure what the diagram looks like. It might look a bit like Figure 1

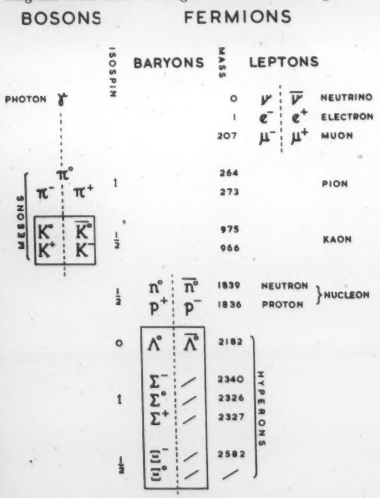

Figure 1

although only a few of the significant features are represented there. The scheme which that diagram indicates must contain a good deal of truth; it has explained and even predicted a fair number of experimental facts.

Nearly all the new particles are unstable and change spontaneously into others and ultimately into stable ones. Among the bosons (i.e. particles obeying Einstein-Bose statistics) the only stable one is still the photon, here denoted by γ (because we mostly deal with γ-rays in this work). Among the fermions (particles obeying Fermi-Dirac statistics and hence subject to Pauli's exclusion principle) our old friends, the electron e^- and the proton p^+, or briefly p, are stable; so are their respective antiparticles, the positron e^+ and the antiproton[1] or negative proton (denoted p^- or $\bar{p}$). Every particle, we believe, has its antiparticle; the two have opposite charge but are identical in most other respects (e.g. mass, spin, or decay rate). So if a particle is stable its antiparticle must be stable too. But when the two encounter each other they are liable to mutual annihilation.

The only other stable particles are the neutrino[2] ν and the antineutrino $\bar{\nu}$; I shall often use the word neutrino to cover them both. It has only recently become clear that the two are distinct: the neutrino always spins anti-clockwise,[3] and the antineutrino clockwise, about the direction of its motion, when viewed from behind. This implies that the neutrino has zero rest mass (like the photon) and hence always travels at the speed of light; otherwise an observer might overtake the neutrino, and then relative to him the direction of flight (but not of the spin !) would be reversed. But if the neutrino has zero rest mass (which we have no reason to doubt) then the relation between motion and spin turns out to be invariant to Lorentz transformations.

Inside a nucleus, the neutron is stable, so we might list it next. Discovered in 1932, the neutron has by now become an industrial commodity; some tons have been produced (and at once consumed !) in the brief history of nuclear power. In the free state it is radioactive and decays like this

$$n \rightarrow p + e^- + \bar{\nu} \qquad (1)$$

* Based on a lecture to the London and Home Counties Branch of the Institute given at the Institute's House on March 19, 1959

at a rate corresponding to a mean life of about twelve minutes. This is the familiar β-decay which also occurs in nuclei with neutron excess ; the neutrino was " invented " by Pauli about 1930 to account for the continuous energy spectrum of the β-electrons.

By why can a neutron not decay simply into a proton and an electron ? Because both those particles have spin $\frac{1}{2}$, and so has the neutron ; and quantum mechanics does not allow us to combine two spins of $\frac{1}{2}$ so as to give $\frac{1}{2}$ again. Hence another spin-$\frac{1}{2}$ particle, uncharged, has to be emitted so as to conserve angular momentum and charge.

In a nucleus that contains too many protons the opposite process is possible

$$[\,p\,] \rightarrow n + e^+ + \nu \qquad (2)$$

The reason why we write ν here and $\bar{\nu}$ in (1) will be discussed later. The square brackets are there to remind us that the proton must be in a nucleus for (2) to be possible.

The pions or π-mesons[4] are related to the nuclear force (by which neutrons and protons are held together in nuclei) rather as the photons are related to the electromagnetic force. Hence pions are emitted from nuclei very easily just as photons are emitted from electric charges. Only one must supply the energy to pay for their rest mass, according to Einsteins $E = mc^2$. All the new particles require energies of from several hundred to several thousand MeV for their production; so we find them among the cosmic radiation, and we can produce them, with much better control, from the fast protons or energetic photons from a high-energy accelerating machine.

Leaving out the energy, a typical pion production may be written as

$$p \rightarrow n + \pi^+ \text{ (a) or } p - n = p + \bar{n} \rightarrow \pi^+ \text{ (b)} ; \quad (3)$$

the " algebra " connecting (3a) and (3b) is based on the useful idea that subtracting a particle is the same as adding the antiparticle. According to (3b), a pion is equivalent to a nucleon-antinucleon pair ; this will be used later.

The neutral pion, π°, is very short-lived ($< 10^{-15}$ sec) and explodes into two photons, suffering annihilation, as it were, with itself. Hence in Figure 1 it has been placed on the dotted line, making it its own antiparticle. This choice can be supported by considering the photon, which has been similarly placed. To go from a particle to its antiparticle is a transformation called " charge conjugation " ; it means (among other things) a reversal of all the electric and magnetic fields. Doing this to a photon merely reverses its phase, leaving it still a photon. So the photon must be considered its own antiparticle ; and so must the π°, because of its ability to break up into photons only.

The charged pion decays with a mean life of $2{\cdot}5 \times 10^{-8}$ sec into a muon and a neutrino :

$$\pi^+ \rightarrow \mu^+ + \nu \text{ (a)} ; \; \pi^- \rightarrow \mu^- + \bar{\nu} \text{ (b)} \qquad (4)$$

The muon[5] (which is quite common among the cosmic radiation at low altitudes) has a somewhat longer mean life of $2{\cdot}2 \times 10^{-6}$ sec :

$$\mu^\pm \rightarrow e^\pm + \nu + \bar{\nu} \qquad (5)$$

After that we have only stable particles left, electrons and neutrinos.

Most of the evidence for the facts I have so far stated rather dogmatically has come from devices by which the tracks of particles are made visible. In the cloud chamber[6] the track becomes visible as a trail of droplets which form around the individual ions which the particle leaves behind on its way through the gas. Droplets will form if the gas at that time contains supersaturated vapour. In the expansion chamber this is achieved by expanding (and thus cooling) the gas, saturated with some vapour. In the diffusion chamber[7] one arranges for the vapour to diffuse from a warm surface to a cold one ; this produces a static zone of supersaturation, in which a particle will form a track at any time. This continuous sensitivity is an advantage over the expansion chamber, which remains sensitive for a fraction of a second only. On the other hand the sensitive layer in a diffusion chamber is not very thick and necessarily horizontal, a drawback with cosmic-ray particles which mostly arrive from above but less so with particles emitted horizontally from an accelerator.

Cloud chambers are often placed in a magnetic field which causes the particles to describe a curved path ; by measuring the radius of curvature of the track one obtains the momentum p of the particle. Sometimes it is also possible to measure (or at least estimate) the number of droplets, and hence of ions, per unit path ; this indicates the velocity v of the particle. From those two data we can compute the rest mass m of the particle by

$$m = p(v^{-2} - c^{-2})^{\frac{1}{2}} \qquad (6)$$

Early determinations of the mass of the muon (then called mesotron, later meson) were mostly made that way ; but the accuracy is poor, in particular when v is close to the speed of light c. Very rarely a muon happens to terminate its mile-long flight through the atmosphere in the gas of the cloud chamber ; then the lucky experimenter can combine the curvature of the track with its range in the gas and get a much more accurate value for the rest mass.

In the last few years another valuable instrument has been developed : the bubble chamber.[8] Here the track is formed, not by droplets in a gas, but by bubbles in a liquid. The liquid is above its boiling point but prevented from boiling by high pressure. At the desired moment the pressure is released for a few milliseconds ; any particle that crosses the liquid during that time produces enough extra heat to cause local boiling, producing a string of bubbles. These are photographed by a bright flash of light within a few milliseconds, before they collapse again as the pressure is restored. The liquid then quickly returns to normal and is ready for another shot within a second or less. By contrast, the expansion chamber usually needs several minutes between expansions. But the greatest advantage is that liquids are much denser than gases (even compressed ones). Collisions between particles and nuclei or electrons are much more frequent ; in a liquid-hydrogen bubble chamber, only protons and electrons are present, which greatly simplifies the analysis. Much faster particles can be stopped in the bubble chamber, disclosing their range, a most valuable quantity ; and

neutral—trackless—particles such as neutrons or photons are much more likely to reveal themselves by producing charged secondaries.

A disadvantage of the greater density of liquids is that the tracks become slightly wavy by the many minute deflections the particle suffers on passing through so many atoms ; because of that " multiple scattering " one needs magnetic fields of 10,000 Oersted or more to get the curvature accurately enough. This trouble gets even worse with the third great track-forming device : the nuclear emulsion.[9] This is essentially a photographic emulsion specially prepared for the purpose of forming many fine grains of silver along the path of a fast particle passing through it. Single layers, mounted on glass as in a photographic plate, are still sometimes used, but more commonly stacks of many layers, pressed together without anything in between. Such a stack is exposed for a suitable time, either to cosmic rays (on a mountain, or hanging from a balloon) or to a selected particle beam from a high-energy machine. It is then taken apart in a darkroom, the single layers are mounted on glass, processed and dried. It is then scanned and measured under a microscope ; individual tracks can often be followed through a number of layers until they stop, disclosing the ultimate fate of the particle, and its range if it has come to rest.

Extremely strong magnetic fields would be needed to obtain tracks with measurable curvature ; but the amount of multiple scattering itself can be measured and gives one pv, the product of momentum and velocity. The ionization density, too, can be estimated fairly well from the number of silver grains per unit track length or—for dense tracks—from the number of gaps in the otherwise continuous line of silver grains. In this way a track one millimetre long may suffice to determine the mass to, say, $\pm 20\%$ and thus to identify the particle.

In all this we have tacitly assumed that all charged particles carry a positive or negative unit charge (i.e. electronic charge). Indeed no exception has ever been found. All " relativistic " particles (with $v \approx c$) have tracks of the same grain density, except for the occasional much denser track of an alpha particle or still heavier nucleus which is easily recognized as such.

One thing the track does not tell us is the sign of the charge ; but that is often revealed when the particle comes to rest in the emulsion. A negative pion at rest is at once sucked into a nucleus where it combines with one of the nucleons (the inverse reaction to (3a)) ; its liberated rest energy causes the nucleus to explode, forming the characteristic " star " of tracks radiating from where the pion had stopped. A negative muon will spend some time in an s-state around the nucleus, passing through it millions of times, but will eventually combine with one of its protons according to

$$p + \mu^- \rightarrow n + \nu \qquad (7)$$

The neutrino takes most of the energy, the neutron most of the remainder ; hence usually no tracks come from the point where a μ^- has stopped in an emulsion.

Positive pions and muons, on the other hand, are repelled by nuclei and left to die a natural death. The pion decays by emitting a muon with a characteristic range of 0·6 mm in a typical emulsion ; from this it was concluded that the other, neutral, decay fragment had little or no mass. It might have been a photon, but no such photons could be found. So we think it is a neutrino, in accord with (4a) ; its intrinsic spin explains why the positive muon, as we now know,[3, 10] possesses a clockwise spin about the direction in which it is emitted. A positive muon emits a positron which may have any energy between zero and 52 MeV ; this agrees with (5) since the rest energy of the muon can be divided in many ways between the three particles, just as in β-decay.

We now come to the " strange " particles which are shown framed in Figure 1 ; why we call them "strange" will be apparent later. Charged K-particles, also called K-mesons or kaons, were first identified in emulsions ; they can decay in a variety of ways, and that caused a lot of confusion. Most easily identified and measured were those kaons (then called τ-mesons) which decayed into three charged pions. The three pion tracks, radiating from where the heavier particle had stopped, were always coplanar, proof that no neutral particles were emitted in the process. From the angles of the three tracks the ratio of the three momenta could be deduced ; if one momentum was known (from multiple scattering or better from range) the whole energy balance could be drawn up and the rest mass of the τ-meson computed accurately.

Other decay modes were harder to deal with, and for some years it was uncertain whether they could all belong to the same kind of particle. If they were different particles they had to have closely similar masses, ever more so as the measurements grew more accurate ; also the proportion in which the various decay modes occurred was not affected by the origin or age of the K-particles. To-day we feel sure that all the observations on K-particles can be accounted for by the two kaons and their anti-particles shown in Figure 1. The neutral kaons behave in a very surprising fashion which I shall discuss later.

The Λ, Σ, and Ξ-particles,[12] which are all heavier than nucleons and are therefore called hyperons, were first observed in cloud chambers. The Λ, being neutral, leaves no track but can be observed when it breaks up, after a mean life of about $3 \cdot 10^{-10}$ sec, into a proton and a π^- :

$$\Lambda \rightarrow p + \pi^- \text{ (a) or } \rightarrow n + \pi^\circ \text{ (b) ;} \qquad (8)$$

some 15% decay as (8b) and usually escape observation. The charged Σ, with a similar mean life, usually also decays in flight (in contrast to the much more long-lived $\pi^\pm$ and μ) :

$$\Sigma^+ \rightarrow p + \pi^\circ \text{ (a) or } \rightarrow n + \pi^+ \text{ (b) ;}$$
$$\Sigma^- \rightarrow n + \pi^- \text{ (c) ;} \qquad (9)$$

the characteristic break in the track where the neutral particle goes off is easily spotted. Notice that the Σ^- is not the antiparticle of the Σ^+ ; the two have different mass. The identification of the Σ° was a triumph of track analysis[13] : it decays (probably within 10^{-20} sec) into a Λ and a photon which can be spotted by the lack of momentum balance among the tracks, and sometimes more directly when it makes an electron pair in the chamber. The charged Ξ-particle is rare, and only a dozen or so have been seen, all negative. It decays into a π^- and a Λ which in turn decays ; for that reason the Ξ is often called the cascade particle. The neutral Ξ

had been predicted for some time on theoretical grounds (see later) ; it is hard to observe since it decays into a Λ and a π^0, both trackless, and the first event of that kind was reported very recently, in March 1959.

After this brief description of our thirty particles, let us look at Figure 1 again. You will see that the fermions are represented in two separate columns headed baryons and leptons (from the Greek words for heavy and light). Those terms were created to help in formulating a reason for some features of stability of our world which were taken for granted without much thought until recently. If an electron and a positron can annihilate each other, why not two electrons ? Well, of course, because electric charge must be conserved, in quantum electrodynamics no less than in Maxwell's equations. But what about an electron and a proton, or about two neutrons ? Their annihilation would conserve charge; yet it must be strongly forbidden, otherwise the world could not have existed its 10^{10} years or so. Indeed a very much lower rate of annihilation could be detected through the γ-rays which would be emitted from all kind of matter. One might think of postulating that only a particle and its antiparticle can annihilate each other, but that is not so : annihilation has been observed between a proton and an antineutron (with charged pions formed to conserve charge).

The current solution is to ascribe to both the proton and the neutron a baryonic charge (the same for both to allow β-decay) which is always conserved. One might identify it with the " charge " that is the source of the nuclear force ; but we have as yet no theory that would impose a conservation law. It is perhaps best not to use the word " charge " but to admit frankly that at present this is a purely formal device. We just ascribe a " baryon number " $+1$ to the nucleon and -1 to the antinucleon, and we postulate that the baryon number of a closed system never changes.[14] This forbids the mutual annihilation of protons and electrons, or of two neutrons, but allows, e.g., that of a proton and an antineutron. Hyperons decay, as we have seen, ultimately into nucleons, so they, too, must be listed as baryons, with baryon number $+1$; antihyperons (only the $\bar{\Lambda}$ has so far been observed) have baryon number -1.

There is evidence that a similar conservation law holds for the leptons, i.e., neutrinos, electrons and muons. That is suggested by the fact that in β-decay ((1) and (2)) and in π-decay (4) an electron or a π^- is always produced together with an antineutrino, and a positron (= antielectron) or a π^+ with a neutrino. This depends, of course, in the first place on choosing the names neutrino and antineutrino appropriately ; but that this can be done consistently implies a law of nature. A check on this became possibly only when it was discovered, early in 1957, that the muons and electrons resulting from those decays tended to spin in a preferential sense about the direction of emission. From many measurements of the direction and intensity of that " polarization," and from more indirect evidence, it was concluded that the lepton number was conserved in most of the experiments ; and those where it was not were later found to have been wrong, a triumph for the principle of lepton conservation.

Now to the column headed " isospin." Soon after the neutron was discovered the theoreticians suggested that the neutron and the proton, in view of their closely similar mass, should be regarded as different states of the same particle, the nucleon. A spin-$\frac{1}{2}$ particle in a magnetic field has two possible orientations, with slightly different energies ; so the nucleon was endowed with a " spin " $T=\frac{1}{2}$ whose two orientations in " charge space " were to correspond to the proton and the neutron. For T, the names " isotopic spin " and " isobaric spin " have both been used ; at present the brief compromise " isospin " seems to be gaining favour. This concept, specious though it looks at first, has been very successful; it allows one to use all the elegant tricks of spin algebra, and many facts about nuclei have been correlated or even predicted.

Strictly speaking, T is a good quantum number only if the properties of the particle or system are independent of its charge. This is nearly true for the nucleon : proton and neutron have nearly the same mass, and the nuclear force is the same, as far as we can tell, between two protons, two neutrons, and a proton and a neutron. So we consider the proton and the neutron as the two components of a " charge doublet " : two states, with $T_3 = +\frac{1}{2}$ and $-\frac{1}{2}$ respectively, of the nucleon, a particle with isospin $T = \frac{1}{2}$. (Arbitrarily, the third co-ordinate of charge space has been chosen as that with respect to which orientation takes place, hence the subscript 3). Again, π^+, π^0 and π^- have very similar masses and similar interactions with nucleons ; so we consider them as a charge triplet, three states with $T_3 = +1, 0,$ and -1 of the pion, a particle with $T = 1$. To the Λ we give isospin zero because no other particle with similar mass is known, and so on.

The difference $Q - T_3$ (sometimes called hypercharge; Q is the charge) is constant within one charge multiplet but varies from one to the other : it is $+\frac{1}{2}$ for the nucleon and the kaon, 0 for π, Λ, and Σ, and $-\frac{1}{2}$ for the Ξ. So a reaction that conserves charge (as it must) may yet fail to conserve T_3 ; and a great many facts fall into place[14] if we assume that such reactions are highly but not completely forbidden.

More convenient than T_3 is the equivalent quantity

$$S = 2(Q - T_3) - n \qquad (10)$$

where n is the baryon number (both Q and n are unconditionally conserved). S stands for "strangeness"; it is so constructed that the ordinary particles, pions and nucleons, have $S = 0$. The others (apart from leptons, see later) were called strange particles because of their strange behaviour. To-day we can define strange particles as those possessing strangeness : $S = -2$ for the Ξ, -1 for the Λ, Σ, and K, -1 for the K, $\bar{\Lambda}$, and $\bar{\Sigma}$, and $+2$ for the $\bar{\Xi}$. (A particle and its antiparticle must have opposite strangeness.)

Strict conservation of S (and hence of T_3) cannot be postulated ; that would forbid the decay of strange particles into ordinary ones, as in (8) or (9). So we must assume that S need not be conserved over the 10^{-10} sec or more, required for the decay of a strange particle ; but we also assume that a change in S is very unlikely during a collision, i.e. in 10^{-22} sec or so. That rule then accounts, e.g., for the absence of the reaction

$$n + n\,(+\text{ energy}) \rightarrow \Lambda + \Lambda \qquad (11)$$

which has been searched for in vain. In fact the rule demands that a collision between ordinary particles can never produce one strange particle but only two (or more) such that their strangenesses cancel. Some typical reactions are shown below, together with the minimum kinetic energy required for the first particle :

$$\pi^- + p \rightarrow \Lambda + K^\circ \text{ (a), } 768 \text{ MeV} \qquad (12)$$
$$\pi^- + p \rightarrow \Sigma^- + K^+ \text{ (b), } 1060 \text{ MeV}$$
$$\pi^- + p \rightarrow \Xi^- + K^+ + K^\circ \text{ (c), } 2840 \text{ MeV}$$
$$K^- + p \rightarrow \Xi^- + K^+ \text{ (d), } 670 \text{ MeV}$$
$$\pi^- + p \rightarrow {}^0\text{n} + K^+ + K^- \text{ (e), } 1360 \text{ MeV}$$

No production process violating the strangeness rule has ever been observed ; on the other hand, the associated production of a kaon and a hyperon, as in 12a and b, has been seen on many cloud and bubble chamber photographs. The rarity of the Ξ^- is plausible from the complexity and high energy requirement of its production through (12c). (12d) requires less kinetic energy ; but the K^-, having negative S, can only be produced with a K^+ or K°, as in (12e) (or even more expensively with an antihyperon), so even by that two-stage process—(12e) + (12d)—the Ξ^- costs 2030 MeV in pion energy. Incidentally, the existence of a Ξ° was postulated because otherwise the Ξ would be a charge singlet and have $S = -3$, which would cause difficulties both with its creation and its decay; so the recent observation of a Ξ° decay is most gratifying.

It will be noticed that the leptons have not been given any S-value. Their interactions with each other and with other particles, far from being charge-independent, are dominated by their electric charge, so the very idea of isospin is inappropriate. But leptons do interact non-electrically with other particles in β-decay, π-decay, μ-decay and some other processes, all of them comparatively slow ; the interaction between the initial and the final state is very weak.

Many features of those " weak interactions " can be quantitatively understood with the help of a diagram like Figure 2. Let us first disregard the lower apex and

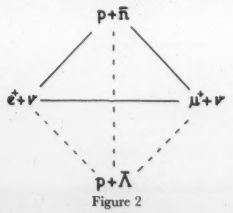

Figure 2

the three dotted lines that radiate from it ; the rest is then the so-called Puppi (or Tiomno-Wheeler) triangle.[14] Any of its sides corresponds to a weak interaction between the states indicated at its two ends. For instance, the top left-hand side corresponds to the following transitions

$$p + \bar{n} \rightleftarrows e^+ + \nu \text{ (a) ; } p \rightarrow n + e^+ + \nu \text{ (b) ;}$$
$$p + \bar{\nu} \rightarrow e^+ + n \text{ (c) ; } n \rightarrow p + e^- + \bar{\nu} \text{ (d), } \quad (13)$$

all of which are identical " algebraically." 13b and d are the β-decays, (2) and (1). 13c is a collision reaction and is thus extremely unlikely to happen in the short time ($\sim 10^{-22}$ sec) of a collision ; but despite the corresponding cross-section of only 10^{-43} cm^2, reaction 13c has been observed[2, 15] by a stupendous effort employing dozens of photomultipliers, large tanks of special scintillating liquid, and an atomic production pile as a source of neutrinos. Similarly the horizontal line corresponds to μ-decay, (5), and the top right-hand side to the capture of a μ^- by a proton, according to (7). This again is extremely unlikely to happen in a single collision ; but when the μ^- has been drawn into a bound state by the electric attraction of a nucleus, overlapping it with an appreciable part of its wave function, then (7) competes with (5) if the nuclear charge $Z \gtrsim 10$.

The Puppi triangle contains fermions only ; but if one replaces its top apex by π^+, in accordance with (3b), one can understand the decay of the charged pion :

$$\pi^+ \rightarrow p + \bar{n} \rightarrow \mu^+ + \nu \text{ (a) or } \rightarrow e^+ + \nu \text{ (b)} \quad (14)$$

(3b) represents a strong interaction and thus does not slow down the π-decay appreciably. The decay (14b) was expected, from theory, to be less likely than (14a) by a factor of about $(m_\mu/m_e)^2 \approx 40{,}000$; after a period of fruitless search—which had the theoreticians worried—the decay (14b) was found last year to occur at just about the expected rate.

With the fourth apex, the Puppi triangle becomes a tetrahedron and now allows us to deal with strange particles as well. The vertical line, combined with (3b), leads (with a little " algebra ") to (8a) and from there through the strong interactions

$$p + \pi^- \rightarrow n \rightarrow n + \pi^\circ \qquad (15)$$

to (8b). But the bottom left-hand side suggests that the Λ should occasionally suffer β-decay :

$$\Lambda \rightarrow p + e^- + \bar{\nu} \qquad (16)$$

and two such events have recently been observed.

Again, just as the top apex is equivalent to a π^+, so the bottom apex can be replaced by a K^+, with a little juggling of (12a), remembering that a pion—with neither baryon nor lepton number nor spin nor strangeness—can always be fitted in as needed to conserve charge, energy or momentum. In this way all the various decay modes of the kaon can be accounted for.

The Puppi tetrahedron enables us to correlate all slow decay processes, and has predicted a good many which have since been found. But moreover one can compute the rates of all those processes by assigning suitable interaction constants to the sides of the tetrahedron ; and the exciting thing is that those interaction constants all seem to be identical.[3] The mathematical form of the interaction, derived largely from the spin behaviour of the emitted particles, again seems to be the same for all the sides of the tetrahedron. Thus we have one universal weak interaction or Fermi interaction, connecting pairs of fermions which appear connected in Figure 2. Not all imaginable pairs of fermions are so connected ; e.g., the decay process

$$\mu^+ \rightarrow e^+ + e^+ + e^- \qquad (17)$$

has not been found although it would be very conspicuous.

The spin behaviour in weak interactions can be summarized roughly by saying that all fermions tend to

spin anti-clockwise, and all antifermions clockwise if viewed from the point from which they have been emitted as a result of a weak interaction. In observing the spin direction—and quite a few methods[16] for doing that have been developed in the last two years—one defines a screw sense : a right-handed screw for antifermions, a left-handed screw for fermions. It was at first a shock to many physicists to learn that " Nature can tell right from left." However, Nature is slow in doing that : only the weak interactions make that distinction. Furthermore the distinction is certain only when we know which are particles and which are antiparticles. The relation between the two is symmetrical, and the assignment has to be made by reference to the protons and electrons in and around us, which we call particles rather than antiparticles. There may be distant " antigalaxies," made of what we call antifermions ; to their inhabitants[17] a right-handed screw, defined by a weak interaction as above, would mean the opposite of what it means to us.

A process which distinguishes between right and left violates a conservation law which, until 1957, was thought to be inviolable : that of parity, a quantum number, either $+1$ or -1, which characterizes the spatial symmetry of a wave function. In all strong interactions, as far as we know, parity is conserved ; but the weak interaction seems to represent a kind of backstairs of physics where both parity and strangeness are of no account. Why those two should associate in that shady manner is not yet fully understood.

As a parting shot, let me say a little about the queer behaviour of the neutral kaons. One of the earliest known decay modes was the break-up into a π^+ and a π^-. Now look at this :

$$\underset{a}{K^\circ \rightarrow \overset{b}{\pi^+ + \pi^-}} \leftarrow \bar{K}^\circ \qquad (18)$$

(18b) is obtained from (18a) by charge conjugation, so both must be equally possible. But that means that the transformation of the neutral kaon into its antiparticle (and vice versa) must be possible through an intermediate virtual two-pion state, and one can show that this can compete with the decay into two pions. In such a situation one constructs two new wave functions :

$$\psi(K^\circ_1) = \frac{1}{\sqrt{2}}[\psi(K^\circ) + \psi(\bar{K}^\circ)]$$
$$\psi(K^\circ_2) = \frac{1}{\sqrt{2}}[\psi(K^\circ) - \psi(\bar{K}^\circ)] \qquad (19)$$

$\psi(K^\circ_1)$ is unchanged by charge conjugation, just like the $\pi^+ + \pi^-$ system ; $\psi(K^\circ_2)$ differs from it by changing sign under charge conjugation. From such an argument (very patchily presented here) it was predicted that a beam of K°-particles should behave like a half-and-half mixture of K°_1 and K°_2-particles, the first ones short-lived and mostly decaying into two pions, the others long-lived and capable of many other decay modes but not of this one. Indeed the two-pion decay is found only along the first few inches of a K°-beam, corresponding to a mean life of $\sim 10^{-10}$ sec ; but half the particles travel on for many feet, decaying into

$$\pi^+ + \pi^\circ + \pi^- \text{ or } \mu^+ + \pi^- + \nu \text{ or } e^- + \pi^+ + \bar{\nu}$$

or in various other ways.

I have said nothing about the important matter of the strong interactions ; those by which nuclei are held together, and others which are studied chiefly through the scattering of mesons and baryons by nuclei. Considerable effort is being devoted to them, both by theoreticians and experimenters, but no simple pattern has emerged as yet. Much of the experimental work is done with cloud or bubble chambers in conjunction with high-energy accelerators. Not many machines in the 1000-MeV region are available : several in the U.S.A., one in the U.K., and a few in the U.S.S.R., France and Italy. The analysis of track photographs is very laborious, and international collaboration is developing between the accelerator operators, the bubble chamber builders and a large number of other laboratories who obtain track photographs for analysis, often using elaborate semi-automatic instruments which record the data on punched tape or cards for processing with electronic computers.

Particles changing into their own antiparticles ; transformations governed by a magic diagram in the shape of a tetrahedron ; conservation laws that you can ignore when you go down the backstairs : what is all this going to lead to ? Not, I feel sure, to a reduction in terms of yet more fundamental particles, as when the 80 odd elements of the periodic table were reduced to electrons, protons and neutrons. Perhaps those thirty particles (and some further ones, I dare say) will ultimately be identified with the solutions of some monstrous future world equation.[18] But first there is a lot more to be found out and to be understood ; both experimenters and theoreticians can see a fascinating time ahead.

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The Physicist in Industry

In November, 1958, the Liverpool and North Wales Branch of the Institute held a well-attended symposium on "The Physicist in Industry." A short account of the meeting was published in the *Bulletin* of December last. We are now able to publish a summary of the opening contribution by Mr. C. S. Bosworth and fuller accounts of the contributions by Mr. J. Bunton and Dr. B. W. Bradford.

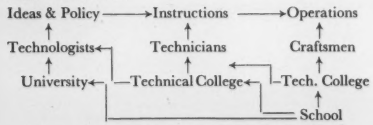
MR. G. S. BOSWORTH
(*Chief of Technical Personnel Administration, English Electric Co. Ltd.*)

THE graduate scientist has lagged somewhat behind his technological colleague in entering industry. It is not so long ago that the graduate engineer was viewed with some suspicion in the engineering industry. The scientist has experienced something of the same reception. It is not surprising that we get the greatest concentration of scientists in those industries which are closest to the science on which they are based, e.g. electronics, aeronautics, guided missiles, atomic power and so on. However, in recent years scientists have been absorbed in increasing numbers into the heavier mechanical and electrical industries and their scope has been much widened. In fact, to-day, in most engineering concerns which accept engineering graduates, the young physicist can expect the same sort of career provided he is willing to acquire the customs, know how, and practice, peculiar to the various aspects of his chosen industry. There is some evidence of unwillingness to accept this on the part of physicists. Many assert that they wish to remain in pure physics and seem to regard technology as a "fate worse than ———." By adopting this attitude they restrict themselves to research, which forms only a part of industry, and deny themselves a wide range of opportunities open to men of good sense and ability.

It is not easy to catalogue jobs which physicists might do. It is better to describe the functions which have to be performed and state that any job can be said to contain one or more of these functions mixed in different proportions. Each function demands different aptitudes and interests against a common background of science and technology. They are :

Mainly Manufacturing Industry	Commerical
	Design and Applications Engineering
	Research and Development
	Manufacturing
Mainly Outside Industry	Operation and Maintenance
	Consulting
	Teaching

Another aspect can be seen by considering the "flow chart" as it were :



Industrial training is usually required in some form or other and takes place by making the young man progress backwards against the flow of ideas and information, on the basis that those issuing instructions are all the better for having had some experience in carrying them out.

Although it is customary for engineers to go into the world of engineering and physicists to follow scientific pursuits this is an outmoded and restricted view. Naturally, the first outlets are found in industry closest to the science from which they spring but the industrial and business world is a large place with a demand for many skills which, even if they are basically scientific, may have only a tenuous relationship with the academic science of undergraduate days. It is surely time for scientists to look in greater numbers for careers in public life, journalism, administration, in the way in which his graduate colleague from the arts side has done for so long.

MR. J. BUNTON, A.Inst.P. (*Mullard Ltd.*)

I believe that the well-trained high-calibre physicist has a bright future, particularly in the electronics industry, and I welcome the opportunity of contributing to this Symposium because I find that if young graduates have given any thought at all to the sort of job they want, they almost invariably say research, without necessarily knowing what other opportunities there are, many of which would suit them better.

First of all may I give you some background of the industry for which I speak tonight. Accurate figures are not easily available but the national turnover is in excess of £300-million per annum and the total number of employees is over 200,000. Out of this turnover, perhaps 40 per cent is concerned with the entertainment industry, mainly radio and television sets, etc., while the rest is concerned with professional and communications equipment. It is this latter group which brings us into contact with so many other spheres of British industry because they are our customers through the increasing use of computers, automatic control, specialized instrumentation, systems engineering, etc.

The industry can be looked upon as a stratified structure in which we have the components supplier (here I include valves) selling to the equipment manufacturer who in turn sells to the user, whether he be the purchaser of an individual television set or a car manufacturer buying an expensive induction heating equipment. Naturally the pattern is not rigid ; many firms have interests in both entertainment and professional equipment manufacture and most make some of their own components. My own Company and its associates in fact, have an interest in all these fields.

One interesting feature of the industry is the attention which the valve suppliers pay to the design of the equipment which uses their valves. This brings them into contact with industrial problems of, shall we say, computer design, or with such matters as the future colour television system to be used in this country. Very large laboratories are devoted to this applications work,

the results of which are made freely available to customers, and so help to develop the market. One important benefit which the valve manufacturer receives of course is that the equipment manufacturer uses the valves under correct conditions and the valve maker learns what valve design he should aim for next.

The rate of growth of the industry can be judged by the fact that turnover in 1938 was only £25-million and many of us feel that the applications of electronics, which in many ways are in their infancy, will play an increasing role in improving the productivity of other industries as well as our own. There will, therefore, be appreciable continued growth in the future.

Naturally when I describe where physicists are employed in this industry I must essentially draw from experience within my own group of companies, which itself occupies a prominent position in the British electronics industry, but is also associated with the international Philips Concern—a world-wide organization comparable in size to the whole of the British electronics industry and covering the full field of activity. In my factual remarks I shall draw only from the Mullard Company, but in experience I am able to draw from this wider background.

We have seven Product Divisions grouped according to the nature of the product, and in each of these divisions there are three levels in which physicists are employed:

(i) Production Organization—including the Central Materials Laboratory.
(ii) Research.
(iii) Commercial and Managerial Organization.

There are, of course, a number of other functions in industry not of interest to the physicist, like financial administration, personnel management, etc.

Let me deal first with the Production Organization. A mass production valve factory, as a typical example, might have the following seven major departments, five of which employ physicists :

Valves
Cathode Ray Tubes
Semiconductors
Magnetic Components
Valve and Lamp Materials
Industrial and Laboratory Apparatus
Telecommunications and Radar Equipment

Both electronic engineers and physicists, may be in the same department and in certain of these cases the work they do is indistinguishable. I shall refer to this later in discussing why we employ physicists.

A highly satisfying and technical career is open to a physicist in a Production Organization of this sort. Students straight from college often state a preference for research not realizing that there are other types of scientific employment, for which some of them at least prove to be better suited both academically and temperamentally.

Perhaps I can amplify by way of illustration the function of Product Development. In a small firm having only one factory, development and design will be undertaken by a section of the Works Organization ; very probably this will have the imposing title" Research and Development Department," although on investigation little, if any, evidence of actual research may be found in practice. A large firm, on the other hand, having several factories may be able to offer the luxury of a Central Research Laboratory serving all divisions of the company. With this type of organization it is possible in practice to distinguish between two types of development —Advance Development, which follows on the results of research and is generally concerned with the application of new principles, and Product Development, which is directed to the preparation of design data in respect of articles actually to be manufactured.

Research and Advance Development are logically conducted side by side in the research laboratory, whereas Product Development and Design are properly the responsibility of the Production Organization. As there is generally an overlap in time between Research and Advance Development and again later between Advance Development and Product Design, the function of development in some firms is associated very closely with research while in others it forms part of the Production Organization.

This is the case in my Company and, of course, once a man is in such an organization he has every chance to settle down properly in that department which suits him, and the company, best. In fact, during the course of his training he will be moved around a great deal so that when he does fill a position of responsibility he can appreciate the contribution which other departments are making. This is a point which cannot be emphasized too strongly because co-operation of a very intimate nature is a necessity in an organization producing of the order of a million electronic devices a week.

Next I should like to refer to our Research Laboratory which is conceived on a central basis to serve the whole Group of Companies. Our philosophy is to maintain a large research organization operating on a broad basis in the fields in which we are interested, and co-operating fairly widely with academic, Government and other institutions. By this means we not only put something back into the economy out of which we make our business—thereby pulling our weight as it were—but also we are in a position to take up any new ideas that come along. We do not expect to trigger off more than our fair share of bright ideas, but we do expect to catch the lift on the first floor on the way up.

A good illustration of this was given by the Research Laboratory of our Dutch associates in 1948, when you will remember the transistor was announced by the Bell Laboratories. The Dutch already had very strong groups working in the Solid State field, who were able to demonstrate the point-contact transistor almost immediately after it was announced.

The Mullard Research Laboratory employs about 700 people and about 60 per cent of the graduates are physicists, the remainder being divided between electrical engineers, chemists and mathematicians, the former predominating.

Its aim is to serve the Company—and through the Company the whole electronics industry—with special materials, components and devices, special units of equipment and comprehensive technical information. System studies and equipment developments are carried sufficiently far to ensure that technical information

originating in the laboratories is both up-to-date and authoritative. It also undertakes work for the Government, the relationship being so close that the laboratories often work effectively as an extension of the experimental facilities of the Government scientific establishments, and frequently take the initiative in determining the scope of the work.

The work of the laboratories is partly directed towards basic research on materials and techniques of interest to the Company, and partly towards the advance development of actual devices, instruments and equipment right up to the prototype stage. The factory development laboratories then take over for production engineering where necessary. The Research Laboratories also provide an important customer advice service to deal with any fundamental problems arising from the use of the Company's products. There is a strong engineering division, with extensive model shop facilities, making possible the construction of complex apparatus and fully engineered models in small numbers where these are needed.

The question of employment of physicists in a commercial or management function is something I prefer to discuss very quickly because it turns on so many other qualities that it is difficult to be precise. Nevertheless I should like to make two points.

(i) This is an industry where it is essential that the product managers and other senior people must know and understand their product. The physicist is naturally in a strong position to fulfil this requirement.

(ii) The physicist has habits of mind which are valuable in equipping him for higher responsibility. I shall return to this point shortly.

And now I must deal with the question of why we employ so many physicists.

I think the first reason is because of our own outlook. We have learned that if we are to keep abreast of developments and reach a high level of productive efficiency, we must understand the fundamentals of what we are doing, and since the physicist is essentially concerned with the fundamental properties of matter and how it behaves, it is natural that he should have a big contribution to make. Let me also make the complementary point that the physicist's outlook suits us. He has probably more in common with the philosopher than any other type of scientist, and has absorbed more fully the scientific method of inductive reasoning. This makes him generally useful in a management sphere even when he is not applying himself to purely laboratory problems.

Lest anyone makes too broad a deduction from my remarks, let me hasten to say that other trainings can be equally valuable ; perhaps I can illustrate this by comparing the physicist's approach with that of a lawyer whose main qualities in the industrial sphere I would summarize as a well-trained memory, relentless logic and the art of fine discrimination.

These qualities are particularly important when distinctions must be drawn between conflicting requirements, when facts must be assimilated over a wide area, and when balanced judgement can only be achieved by walking a precarious tightrope. There are spheres of management activity where such an approach is indispensable but there are others where the physicist's mental habits are equally valuable. His conviction that one can always refer back to first principles gives him a commendable laziness to the memorizing of detail, and his willingness to introduce hypothesis often brings a welcome freshness of approach which rises above the weariness of the problem in hand. These attitudes of mind are essentially complementary and each can find its niche in a large industrial concern ; no single training monopolizes the road to success, but the need for a scientifically-minded individual at the highest level of management was never greater.

The second reason, of course, is that the physicist's knowledge suits us—as long as he is the right sort of physicist. The man who is interested in vacuum physics, or gas discharge problems, is a natural recruit, but for many years now attention has been paid to the study of solid state physics and this will become increasingly important as more solid state devices like transistors, photoconductive cells, electroluminescent devices, etc., are introduced. But it is interesting to notice that we are finding more use for the theoretical physicist, particularly in our research laboratories. This is not only in his capacity to interpret the results of his experimental colleagues but as the man who can produce models, explain results and guide them in their experiments. In fact, he often makes an excellent team leader and this is a trend which might easily develop.

Perhaps it would not be inappropriate here to say something about the relationship between the physicist and the electrical engineer in the electronics industry. You have probably heard that the difference between them is that whereas both are quite capable of designing a little black box to do a certain job, the physicist sees no difficulty in screwing on the lid from inside. You probably think that this maligns an honourable profession, but the element of truth it contains is reflected in the fact that our Equipment Factory employs effectively no physicists, either in its Development Laboratory or its Production Department. Nevertheless, as I have already said, our Research Laboratory employs 60 per cent physicists and our Valve and Transistor Factories a like percentage, and it is quite common to find physicists and engineers working side by side on a project.

The reason lies in their different approaches. The engineer is much more concerned with the apparatus used either as an engineered product or as an effective means of executing the experiment, whereas the physicist is much more interested in the properties of the materials used, the limits of which determine its performance, and the interpretation of the measurements in physical terms. Let me illustrate my point :

(*a*) In the examination of ferrites at microwaves the physicist is interested in the directional properties of the ferrites under various conditions, but when it comes to designing a uniline or a circulator which can be built into a radar system it is best to leave it to the engineer.

(*b*) The physicist will be much more interested in the properties of germanium or silicon or of semiconducting compounds as suitable materials for transistors, but the engineer is more able to produce a device capable of manufacture.

It is because the physicist is concerned with fundamentals that he is so adaptable, and we find it far more common for the physicist to produce the requisite knowledge of physical chemistry or circuit technique in order to do a job, than the other way round. It is from this broad base that he makes his sallies into other spheres of influence.

Now perhaps I may be permitted a few minutes to say what the electronics industry has to offer a physicist. This is not the right place to talk about such material provisions as salary, pension, holidays, etc., but anyone who wants to know can always ask me privately.

The first point I should like to mention is that he can obtain satisfaction in a wide variety of jobs. It is not always realized at the student level that personal satisfaction in a job is at least as important as the more obvious attractions, and depends as much on the individual's temperament as on the nature of the work. Some men are by nature research types ; they like to have a long-term problem they can live with and to which they can devote their whole energy even if no tangible solution is forthcoming for years. The personal satisfaction to be derived from research and development differs. The development engineer has to create something and he encounters many problems, each of which is a challenge to his ingenuity and resourcefulness. At all times he has the end product in mind and his satisfaction comes from building his prototype, and later seeing his design embodied in a finished product.

My experience is that men who want to do research all their lives are comparatively rare ; there are many who want to do it in their youth, but having got it out of their system, they find that they are really interested in the challenge of development with its timing problems or of production with its accent on efficiency and cost factors. It is natural therefore, that one finds a tendency for people to move from the research laboratory into other departments, which enables them to find the outlets they want in life, and promote good relations between the research laboratory and the rest of the organization. It also keeps the laboratory young in outlook and gives the individual greater opportunity for advancement than would normally be available within a pyramidal structure.

I think it is true to say that whether a man is an individualist who prefers to work on his own, perhaps with a view to a higher degree, or whether he is essentially happier in a team working on a big project, he can find a post which will suit him. The individualist will probably be more at home in a research laboratory but on the whole, the man who has those qualities of co-operation and sometimes the self-denial which team work demands, is likely to go furthest.

The second point is a corollary of the first inasmuch as it relates to the wide variety of work which presents itself. A physicist working in one of the larger research laboratories might be concerned with the instrumentation for a nuclear reactor, or with the problems of control engineering in which he is developing electronic machines which would weigh, count, sort or measure. He may be involved in the problems of nuclear magnetic resonance or with the design and drive of a memory store for a large computer. Or he may just be concerned with the basic properties of the materials used and why electrons or holes behave as they do under various circumstances. We hope for his sake, and for ours, that he will not try to concentrate on all this at once, but the possibility is open to him and he will be unusual indeed if some problem cannot be found which will extend him.

The third attraction the electronics industry offers is the opportunity to participate in a fast-moving industry which itself is contributing to the activities of many other sections of British industry—sometimes with a rejuvenating effect. The rate of the spread of electronics can be gauged from the fact that valve sales expanded from 15 million valves in 1946 to almost 80 million in 1956. In the meantime the transistor had appeared and very rapid strides had been made in the development of microwave valves, and numerous other devices are just around the corner. In fact one of our main difficulties is to digest the results of our own researches.

From all this I hope you will have gained the impression that the electronics industry is not only a worthy employer of physicists but also a respectable one. From every point of view both materially and otherwise, it has a great deal to offer, but I should be less than just if I failed to point out that it also demands a great deal. The standard of entry into a major research establishment is high and the calibre of work is of a like quality. But that need not deter a young man who has the right training and an adaptable nature so that he can use his knowledge of physics to the greatest advantage. Perhaps I can repeat one of my earlier remarks—that for the well-trained, high-calibre man, the future in this industry is bright.

DR. B. W. BRADFORD

(Director of Research, Billingham Division, Imperial Chemical Industries Ltd.)

It is often assumed that the physicist has only a very minor part in the chemical industry. I shall try to show you that this is far from the truth. While it is primarily the domain of the chemist and the engineer, physicists are indispensible to it. In thinking of the chemical industry it is appropriate to include not only the manufacture of chemicals as ordinarily understood—such products as acids, alkalis, fertilizers, explosives, pharmaceuticals, dyes and plastics—but also the oil industry. These are all related and what I have to say refers equally to all of them. To put the size of this industry into perspective, the broad definition which I have taken comprises much the largest industrial group in the country, amounting to about one-sixth of the total.

It is difficult to obtain reliable data on the employment of physicists but it appears that of the 600 or so physicists graduating each year about 10 per cent enter some branch of the chemical industry. It is therefore one of the largest employers of physicists in the country.

Although diverse in products and processes, there are two factors, important in the present discussion, which are found in most branches of the chemical industry. Firstly, it is an industry which is mainly of recent development and one in which requirements change rapidly ; it therefore cannot survive without active research and development. Its staff must be technically up-to-date

and it is under continuous pressure, not only to maintain and improve its current standard of efficiency but to devote much of its effort to planning five or ten years ahead—the period which is needed to develop a new process or product from the laboratory to the full scale. Secondly, much of the chemical industry, perhaps two-thirds of the whole, is concentrated in a limited number of large firms. Only a very large unit can afford the overhead cost of research and development required in the chemical industries. Size alone has no special virtue but only in a big organization can full opportunities be found for a diversity of science as well as a sufficient number of avenues for the advancement of the able and ambitious individuals without whom no organization can be healthy for long.

With that introduction I shall try to show the place and prospects of physicists.

We can consider the work of physicists under three headings : research, technology, and management. I use this sub-division only because a physicist must start somewhere when he enters industry, but I want to emphasize now, and I will develop the point later, that the individual may, and often does, progress from one of these branches to another.

A research department in the chemical industry usually finds itself with very wide responsibilities for services and investigations of various sorts, in addition to its prime function of finding and applying new ideas. So the physicist will find a whole range of functions to choose from or be called upon to fulfil.

Physical chemical research is closely allied to physics in all its branches and the physicist has a natural place in this field. Of the many examples which might be mentioned I will select a few : solid state physics is the basis of much of the theory of catalysts, those all-important parts of many chemical processes. The recent development of semi-conductors is an allied subject. Radiation properties and phenomena throughout their whole wide range are primarily physical. Spectroscopy, one of the most powerful of the chemists tools, is essentially a branch where the physicist has to provide the method and the chemist uses it to solve his special problems. Radio-chemistry and the developing use of nuclear properties are as much the concern of the physicist as of the chemist. Electrical discharge phenomena, the theory and understanding of explosions, the complicated range of metal physics, are all intimately bound up with different aspects of chemical research. The study of disperse systems, aerosols and colloids needs a physicist as an integral part of a research team and in such work there is a special need for physicists with a broad background in classical physics.

The mathematical side of physics must not be overlooked either. It provides a fundamental background to much of engineering, chemical engineering and instrument theory. To mention again only a few aspects—the flow of liquids and gases, transport phenomena, the transfer of heat and of matter are basically branches of physics.

A new and important subject in industrial chemistry is the theory and practice of automatic control systems which are rapidly transforming processes and plant. Another is high-speed computation which can only be properly developed and applied by the physicist and the mathematician working together.

The rate of progress of chemical research is often a function of the rate of progress of methods of separation and measurement and it is scarcely necessary to say that physical methods are becoming every year more important. It is the physicist's role to provide the tools and one need only think of electron microscopes, X-ray diffraction, optical spectroscopy and mass spectrometry, as new, powerful analytical and structural methods which have sprung from the work of physicists and need the physicist to keep them in proper order and develop them still further. There is no foreseeable end to this process.

So far I have considered the physicist as a member of the research teams in an industrial chemical laboratory. In fact, most of the physicists working in the chemical industry are concerned with physical measurements of the properties of working materials and final products and here a more technological interest enters. Even when the quality of a material is measured in terms of chemical analysis, the problem is often a physical one. When the apparatus used in the research laboratory begins to have applications in routine work for quality testing the instrumentation aspects begin to develop. There are clearly two stages involved in this. There is first the problem of adapting and modifying equipment satisfactory in a research laboratory but unsatisfactory for routine or plant use and engineering it in such a way that it suits its new environment. Here the physicist joins forces with the engineer and the instrumentation field is one of the most important for the physicist. Once an apparatus is fully developed there follows the need to install it correctly and to ensure that it operates accurately and continuously. We therefore find a natural development from the physicist in the research laboratory to the instrument expert.

Instrumentation problems in chemical plant are specialized and involve a great deal of co-operative work between, in the first stages, the analyst, physical chemist and physicist, passing on to the instrument specialists and chemical plant operators. All these are necessary before the usefulness of an instrument can be assessed and before it can finally be brought into successful operation in a plant.

I have spent rather a long time on the functions which the physicists fulfil because I have been trying to show that the physicist has an integral part to play and is not pushed into a backwater simply because the chemical industry is primarily a matter for chemists and engineers. This is not so, and indeed chemists and engineers cannot do without physicists.

The young physicist joining some branch of the chemical industry will in many cases first enter the research laboratory, either joining a research project in physics, physical chemistry or chemical engineering, or an instrument research and development team. The laboratory world is one with which a young physicist is familiar and three or four years in it give him a chance to show his merit and learn something about the industry in which he has chosen to make a career. Thereafter several avenues are open and the one which is chosen will depend primarily on the man's own

preference. He will do best in what he likes best and the choice is not really a difficult one. Only a small proportion will choose research as a career because as a general rule (and this applies to other sciences than physics) there are not many who are suited to a life of research.

Whatever his future is likely to be, it is a good thing for him to spend a few years on the production side of the business. Here his interest is primarily technological and he usually enters the instrumentation organization and becomes responsible for the proper functioning of plant instruments and control systems. It is only necessary to say that from five to fifteen per cent of the new capital of a chemical plant is spent on instruments to make it evident how important this is. A modern large, continuously operating chemical plant cannot afford inaccuracy or inefficiency in its instruments. In fact, the evolution of chemical plant and processes is dependent upon the evolution of instrumentation and the physicist turned instrument expert has become a very important person. He supplies the control theory and practice on which new and better plants and processes depend and which give not only higher efficiency and productivity but improve working conditions as well.

The planning and design of new plants cannot nowadays be undertaken without full participation, from the beginning, of experts in instrumentation and control. This is one of the most rapidly developing branches of technology at the present time, and it involves the physicist both in the fundamental field of control theory and in the design, application and operation of instrument systems.

From all this, the individual physicist's rewards follow naturally. He is a vital part of the technical and management structure and he should share, and in my experience does share, all the prospects open to his chemical and engineering colleagues. Responsible posts are open to him in research, in technical fields and in management. In the organization of which I can speak, physicists are to be found in senior posts at all levels up to the top. So far as I am aware there is no occupational hazard in being a physicist in the chemical industry. It needs more physicists and not only those with a leaning towards instrumentation. It needs more physicists with academic research experience and it needs more with a broad scientific outlook and education who can bring their special contribution and take their place in running, managing and directing a scientific industry.

Correspondence

Graduateship Examination

Comment in the May *Bulletin* regarding Professor Lipson's paper in the 1958 Graduateship examination calls to mind a true incident concerning a physics lecturer in a college at which I then was.

He set his class some problems, and wrote out his own solutions. Later, when the scripts were collected, these solutions were included among the scripts. The result was that he marked his own solutions—and gave himself six out of ten !

J. J. PARKER (*Associate*).

118 Coleshill Road,
Birmingham 34.

Biological Hazards of Ionizing Radiations

As a medical radiologist, I would like to question some of Professor Rotblat's observations in the April *Bulletin*. According to him, " until we know better we must assume the worst." If we really went on that principle, could we take a bite of food or a breath of air ? Certainly one could not cross a street nor drive a car.

Was the " hazard " from medical X-rays really " discovered " by " Committees which were set up to investigate the fall-out " ? Would he maintain that the association of road accidents with speed was " discovered " by the Ministry of Transport and this led to the fixing of the various speed limits ? Having " found " the appropriate figure, should they not have gone on to insist that vehicles should be fitted with governors to prevent them exceeding it ?

Of course, an ambulance would not be of much value in getting a patient to hospital if it is driven too fast and is involved in a crash : but it would be no more use if it takes so long that he has succumbed to his illness before it arrives. We have to make some sort of compromise between driving too fast and taking too long, although these risks are not commensurable.

Similarly, the suggestion that there would be less risk if we took fewer films is analogous to saying that there would be less risk of road accidents if vehicles were kept in the garage, in which there is doubtless some truth, but it does not meet the need for transport. We cannot organize our lives to avoid risks altogether : the question surely is, " What are the most sensible risks to take ? " This is a question of *policy* rather than of fact, and a physicist should be the last person to make such a confusion.

I should like to make it plain that radiologists are generally willing to take reasonable directions from physicists—as also from the traffic police—when they understand it to be for the general good : but attempts to impose senseless restrictions or officious opinions will be liable to provoke the sort of " cold war " which existed between police and motorists in the early days of the Automobile Association.

Then we are told that Professor Rotblat has "evidence that radiologists suffer more often from leukaemia than other medical practitioners." Does he consider that the relatively high incidence of coronary thrombosis in general practitioners reflects the danger of using the stethoscope ?

On the other hand, he is satisfied that " There is no evidence of any beneficial effects of small doses of radiation." That surely depends on what you mean by " beneficial effects." Kaplan at the 7th International Congress of Radiology in 1953 (Paper T 120), reviewed

individually several grandchildren of women who had been treated by radiation for sterility. All the children appeared healthy and none showed any physical or mental defect. But no doubt it will not escape the pessimists that one of them may yet press the button for the explosion to end all explosions.

I would not of course maintain that common sense can never be seriously misleading, or that it should be preferred to physical laws or experimental results soundly established. It may be salutary to reflect, for example, how many people lost their lives in the *Titanic* because they failed to appreciate the Principle of Archimedes.

On the other hand it is surely wise also to recognize the limitations of the scientific method, as Professor Woodall observes in the same issue of the *Bulletin*. For who can calculate the consequences—even the probable consequences—if Cæsar had decided *not* to cross the Rubicon, or if the Romanovs had *not* suffered the hæmophilia mutation—perhaps from a single quantum? So why should we " maximize Pessimism " ? Has the situation really changed so radically since Professor Lamberton's Presidential Address to The British Institute of Radiology last year (*Brit. J. Radiol.*, 1958, xxxi, 229), which Professor Rotblat appears to have ignored ?

M. B. Leitch.

Law Hospital, Carluke, Lanarkshire.

Professor Rotblat comments as follows:

Most of Dr. Leitch's criticism is misdirected, because nowhere have I advocated abandoning the use of radiations on account of their possible harm. In relation to diagnostic radiology, about which Dr. Leitch is naturally most concerned, I said that one could cut down considerably the X-ray dose without affecting the benefits from X-ray examination. This is a generally accepted view, and not only by physicists. When I speak on this subject to the general public I advise them to leave to the doctor the decision whether an X-ray is necessary or not ; I always stress the importance of balancing the definite advantage of an X-ray examination against the very small chance of damage. In the article I summed up this attitude in relation to the whole subject when I said that the various uses of radiation confer on us definite advantages and that the possible harm must be balanced against the definite benefits.

I object to Dr. Leitch citing me out of context. He quotes the sentence " There is no evidence of any beneficial effects of small doses of radiation," but ignores the next sentence in which I say the same about the harmful effects. I know of Kaplan's paper, but I also know of a dozen other papers purporting to show the harmful effects of small doses of radiation. I still maintain that in none of these papers have the effects of small doses of radiation been definitely established.

I intended the article to be a general review of the whole field and to present not necessarily my own views but those generally accepted. Most of the data, including the " pessimistic " estimates, are taken from the Report of the United Nations Scientific Committee. Since, however, Dr. Leitch attacked me for putting forward my " policy," let me at least state it : I believe that the general public should be treated as intelligent beings and taken into complete confidence. We should tell them how much we know and how much we do not know, and what might be the risks under the worst conditions. We should then go on to point out the benefits which will arise from the use of radiations. I am sure that in these circumstances, the public will accept the small risk, just as they have accepted the many other risks of modern life. If, on the other hand, we try to play down the risks, if we make soothing statements which have to be withdrawn, if we keep talking about " safe " levels which have to be periodically revised downwards, we only create suspicion and make the public lose confidence in us. The events of the last few weeks have demonstrated this amply.

Forthcoming Institute Meetings

July 7 to 10	**Exeter** The University	Annual Group Conference	Electron Microscopy
July 8	**Buxton** and **Chapel-en-le-Frith**	Summer meeting and visit to the Ferodo Laboratories of Turner & Newall Ltd.	Yorkshire
July 18	**Cambridge**	Summer meeting and visit to the Cavendish Laboratory and to the Mullard Radio Astronomy Observatory.	Education

Primarily for members of the Group and their guests. Registration is necessary.

Notes and News

The British United Provident Association : Group Scheme for Institute members.

Many members will be familiar with the form of insurance against the cost of nursing home fees, surgical operations and specialist treatment provided by non-profit-making organizations such as the British United Provident Association. The Board of the Institute has agreed to sponsor a Group Scheme of insurance with this body and this will be open to Fellows, Associates and Graduates of the Institute and to the permanent staff. A Group Scheme provides significant advantages, including a 20% reduction of the standard rates of subscription and the waiving of the normal waiting period of three months.

Members who would like to have details of the benefits and subscriptions may obtain them from the Secretary of the Institute.

South Western Branch

The date of the Summer Meeting of the Branch at Shrivenham was unfortunately announced in the May issue of the *Bulletin* as June 19. The meeting will in fact be held on **June 26.**

Conference on " Some aspects of magnetism "

As was announced in the December, 1958, *Bulletin*, the Institute is arranging a Conference on " Some aspects of magnetism " to take place in Sheffield from September 22-24, 1959.

The subjects to be covered at the Conference are :

(*a*) Fundamental theories of ferro-, ferri- and antiferromagnetism, including magnetic structure.

(*b*) Theories of technical magnetization processes, including hysteresis, coercivity, anisotropy and directional effects.

(*c*) Theoretical and experimental studies of domain phenomena in bulk materials and thin films.

(*d*) Experimental and theoretical studies of antiferromagnetism in metals and non-metals.

Each session will be opened by an invited speaker. The conference is intended mainly for persons working in the field. Abstracts (but not preprints) will be circulated before the Conference, the proceedings of which will not be published in full.

Those wishing to attend should obtain programs and application forms from the Secretary of the Institute as soon as possible.

Radiofrequency spectroscopy meeting

A conference on radiofrequency spectroscopy will be held at the Clarendon Laboratory, Oxford, on September 17 and 18, 1959. The conference will be devoted to the radio-frequency spectroscopy of free atoms and molecules, and there will be sessions on atomic beam and optical methods, microwave gaseous spectroscopy and the measurement of fundamental constants by radio-frequency methods. Registration forms (with requests for accommodation which must be returned before July 1) can be obtained from Professor B. Bleaney, F.R.S., Clarendon Laboratory, Oxford.

Physical Society conferences

The Physical Society has arranged the following conferences : July 5 to 7—King's College, Newcastle, on Co-operative Phenomena and Phase Changes ; September 14 and 15—Edinburgh, on Nuclear physics ; September 17 and 18—Imperial College, London, on Plasma physics ; December 17 and 18—Oxford, on Electron-phonon interaction in solids.

Hospital Physicists : Health Physics Sub-Committee

The Hospital Physicists' Association has set up a Health Physics Sub-Committee to advise the Executive Committee (and the Association) on matters connected with this subject. The Honorary Secretary of the Sub-Committee is Mr. S. B. Osborn, A.Inst.P., University College Hospital, London, W.C.1.

Physics Masters

In the House of Commons on April 30 Mr. Sorensen asked the Minister of Education to what extent there is a shortage of physics masters in grammar schools, particularly in the administrative county of Essex ; what are the prospects of overcoming this shortage during the next five years ; and what action he has taken to secure the retention of physics masters in grammar schools who may still be liable to National Service.

Sir Edward Boyle replied that last October there were twenty-six vacancies for physics graduates in boys' grammar schools in England and Wales, but none of these was in Essex. He thought it highly likely that the shortage in these schools will be overcome quite soon. The deferment arrangements have recently been extended, so that all physics graduates who complete their degree course in 1959 are eligible for deferment for teaching.

Scientific Education of Physicists

A completely new edition of *The Scientific Education of Physicists*, which includes details of the physics departments of all the British universities and those technical colleges recognized by the Institute, is now available. Copies may be obtained free of charge from the Deputy Secretary.

A Physics Anthology

As has been previously announced, the Deputy Secretary, as Editor of the *Bulletin*, was asked to select a number of articles from the *Bulletin* for publication in book form. The selection of twenty-two articles is now at press, and will be published with the title *A Physics Anthology*. Further details, including the price, will be announced later.

International Tables for X-ray Crystallography

Volume II (Mathematical Tables) of the *International Tables for X-ray Crystallography*, published for the International Union of Crystallography, is now ready. The price is £5 15s. 0d. inclusive of postage and packing, but members of the Institute may obtain one copy, for their **personal use** only, at the subscription price of £3 10s. 0d. post free by using a special order form available, with the prospectus, from the Kynoch Press, Witton, Birmingham 6.

The Annual Dinner

The Annual Dinner of the Institute was held at the Park Lane Hotel, London, on Tuesday, May 5, and was attended by about 270 members and guests. They were received by the President and his daughter, Mrs. Jan de Villiers Graaff.

Sir George Thomson and his daughter, Mrs. Jan de Villiers Graaff.

The Institute's official guests, most of whom were accompanied by their ladies, were Sir Keith Murray (*Chairman, University Grants Committee*), Sir Harry Melville (*Secretary, Department of Scientific and Industrial Research*), Sir Owen Wansbrough-Jones (*Chief Scientist, Ministry of Supply*), Dr. T. H. Osgood (*Scientific Attaché, U.S. Embassy*), Mr. G. L. Bailey (*President, Institute of Metals*), Mr. T. C. Bailey (*President, Institute of Fuel*), Mr. S. E. Goodall (*President, Institution of Electrical Engineers*), Dr. A. S. Parkes (*President, Institute of Biology*), Professor A. J. S. Pippard (*President, Institution of Civil Engineers*), Mr. J. A. Ratcliffe (*President, Physical Society*), Mr. F. W. W. McCombe (*Chief Commissioner, Charity Commission*), Dr. G. B. B. M. Sutherland (*Director, National Physical Laboratory*), Mr. W. K. Brasher (*Secretary, Institution of Electrical Engineers*), Dr. J. B. Brennan (*Secretary, Institution of Chemical Engineers*), Mr. D. J. B. Copp (*Secretary, Institute of Biology*), Dr. H. J. T. Ellingham (*Secretary, Royal Institute of Chemistry*), Mr. A. J. V. Gale (*Editor, "Nature"*), Lieutenant-Colonel F. J. Griffin (*Secretary, Society of Chemical Industry*), Dr. D. C. Martin (*Assistant Secretary, The Royal Society*), Mr. A. McDonald (*Secretary, Institution of Civil Engineers*), Mr. R. G. S. Ludlam (*Secretary, Institution of Metallurgists*), Mr. R. W. Reynolds-Davies (*Secretary, Institute of Fuel*), Dr. A. C. Stickland (*Secretary, Physical Society*), and Mr. K. E. Kay (*The Institute's Advisory Surveyor*).

Past Presidents who attended were Sir Lawrence Bragg, Professor A. M. Tyndall and Mr. O. W. Humphreys.

The toast of The Institute of Physics was proposed by Sir Keith Murray, and the President replied.

Mr. Humphreys proposed the toast of the guests, to which the reply was made by Sir Harry Melville.

Sir George Thomson, Mrs. Humphreys, Prof. A. M. Tyndall, Mrs. Jan de Villiers Graaff and Mr. O. W. Humphreys.

(From extreme left, clockwise), Mr. A. McDonald, Mr. K. E. Kay, Mrs. McDonald, Dr. D. C. Martin, Mrs. Kay, Mr. W. K. Brasher, Mrs. Martin, Dr. H. R. Lang, Mrs. Brasher, Dr. A. B. D. Cassie and Mrs. Lang.

(On the left)
Mr. and Mrs. A. J. Ratcliffe being received.

(On the right)
The President and Mrs. de Villiers Graaff with Mr. and Mrs. P. R. Coursey.

(From extreme left, clockwise)
Dr. R. Beeching, Mrs. Davies, Mr. E. R. Davies, Mrs. Martin, Mr. T. Martin, Dr. M. R. Hopkins, Mrs. Menzies, Dr. A. C. Menzies and Mrs. Beeching.

(Left to right)
Lady Bragg, Sir Harry Melville, Mrs. Ratcliffe, Sir Keith Murray, the President and Mrs. Humphreys.

(From left, clockwise)
Dr. R. S. Silver, Mrs. Spalding,
Prof. D. B. Spalding, Mrs. Silver,
Mr. G. B. Oddie, Dr. J. M. A. Lenihan,
Mrs. Burnett, Mr. R. E. Burnett,
Lady Crow and Sir Alwyn Crow.

Dr. and Mrs. J. Taylor being received.

Mr. N. Clarke with Mr. and Mrs. B. Barber.

Mr. A. Tybulewicz, Mrs. Topping,
Dr. J. Topping and Miss T. Bryl.

News of Members

FELLOWS

T. Thorne Baker is a Consultant at the Thorne Baker Laboratory, Pinner, Middlesex.

C. R. Burch is to give the 1959 Parsons Memorial Lecture on Aspheric Reflecting Microscopes.

P. J. Duncton is now Technical Manager (Atomics) at Fairey Aviation Ltd., Heston Division, Hounslow, Middlesex.

J. V. Dunworth is Assistant Director of the Research Group of the United Kingdom Atomic Energy Authority.

G. F. Hodsman has taken an appointment as Chief Design Engineer with W. & T. Avery Ltd., Soho Foundry, Birmingham.

O. W. Humphreys (*Past President*) has been elected Vice-President of the Institution of Electrical Engineers.

Sir Willis Jackson has been elected President of the Institution of Electrical Engineers, and will take office next October.

S. C. Jain has been appointed Senior Scientific Officer Grade 1 at the National Physical Laboratory of India, New Delhi.

Professor W. C. Price has been elected a Fellow of The Royal Society.

Professor G. V. Raynor has been elected a Fellow of The Royal Society.

T. Ll. Richards has recently taken up an appointment as Reader in Physical Metallurgy at the College of Technology, Birmingham.

R. S. Silver has now joined the Board of G. & J. Weir, Ltd., as Technical Director.

R. W. Stanford has been appointed Head of the Department of Medical Physics at the Royal Perth Hospital, Perth, Western Australia.

C. R. Tottle has been appointed Professor of Metallurgy and Director of the Metallurgical Laboratories at the University of Manchester.

N. Tunstall is now at Lowther College, Abergele, North Wales.

Professor A. M. Tyndall (*Honorary Fellow and Past President*) has received the degree of LL.D. (*honoris causa*) of Bristol University at the special conferment of Honorary Degrees to mark the jubilee of the University.

Professor F. A. Vick (*Honorary Secretary*) has been appointed Deputy Director of the Atomic Energy Research Establishment at Harwell.

W. H. Walton has recently been elected President of the British Occupational Hygiene Society.

R. V. Whelpton has been promoted to deputy chief scientific officer and appointed Ministry of Supply representative on the Defence Research Policy Staff at the Ministry of Defence.

ASSOCIATES

W. A. D. Baker has been appointed Physicist in the Research Laboratories of Sidney Flavel & Company Ltd., Leamington Spa.

J. S. Buchanan is now in the Packaging Research and Development Division of A. E. Reed Ltd., Maidstone, Kent.

F. H. C. Crick has been elected a Fellow of The Royal Society.

C. Curry has been appointed a Senior Lecturer in physics at the University of Leeds.

J. J. Gameson is now Senior Transistor Applications Engineer at Clevite Transistor Products, Waltham, Mass., U.S.A.

E. L. Garrett has taken an appointment as Physicist in the Industrial Design Department of Vickers Armstrong (Aircraft) Ltd., Swindon, Wilts.

G. George has been appointed Headmaster of Pontllanfraith Grammar Technical School.

D. F. Gibbs is now a Senior Lecturer at Bristol University.

D. L. Goldby has taken an appointment in the Patent Office of the Board of Trade.

G. Haigh is now a Physicist with the Iraq Petroleum Company Ltd. in the Reservoir Engineering Laboratory, London.

J. C. Hammerton is now with the Teleregister Corporation, Stamford, Conn., U.S.A.

A. H. Hayward is now Headmaster of the Hemel Hempstead Technical High School.

H. T. Heal is a Principal Scientific Officer at the Admiralty Compass Observatory, Slough, Bucks.

J. P. Henderson has been appointed Director of the East African Meteorological Department in Nairobi, Kenya.

E. J. F. Hodgett is now a teacher of physics at the Methodist College, Belfast.

P. J. Jutsam has been appointed Lecturer at the University College of the West Indies, Jamaica.

J. H. McGuire is in the Division of Building Research (Fire Section) of the National Research Council, Ottawa, Canada.

J. Nortcliffe has taken an appointment as Instrument Project Engineer with Esso Petroleum Company, Southampton.

G. C. E. Olds has been appointed Head of the Physical Metallurgy Section in the Group Research Laboratory of British Thomson-Houston Company Ltd., Rugby.

W. T. Roberts is now a Lecturer in the Department of Industrial Metallurgy of the University of Birmingham.

D. A. Robins has taken an appointment as Chief Metallurgist in the Tin Research Institute, Greenford, Middlesex.

R. B. Sims has taken an appointment as Chief Engineer in the Darnall Works of Davy and United Engineering Company Ltd., Sheffield, and has also been awarded the W. H. A. Robertson Medal and Premium by The Institute of Metals.

R. Stratton has taken an appointment in the Central Research Laboratories of Texas Instruments Incorporated, Dallas, Texas, U.S.A.

L. Thomas has been appointed Senior Scientific Officer at the Department of Scientific and Industrial Research Radio Research Station, Slough.

S. W. Thorne is now Senior Research Officer at the C.S.I.R.O. Division of Plant Industry, Canberra, Australia.

A. J. F. Trott has taken an appointment with Plessey Nucleonics Ltd., Northants.

L. A. Walker has been appointed Senior Lecturer in the Engineering Department of the College of Advanced Technology, Birmingham.

E. C. Williams has taken an appointment as Manager of the Research and Development Department of Steatite and Porcelain Products Ltd., Stourport-on-Severn, Worcs.

GRADUATES

A. Bland has been appointed Physicist at A. E. I-John Thompson Nuclear Energy Company Ltd., Knutsford, Cheshire.

B. B. Cartwright is now a Production Engineer with Havic Ltd., South Ruislip, Middlesex.

C. Charlton has been appointed Research Engineer at Boeing Airplane Company, Seattle, Washington, U.S.A.

J. A. Cheatham has taken an appointment as Project Leader at the Wiggins Teape Group Research Organization, Beaconsfield, Bucks.

T. C. Duggan is now Senior Physicist (Honorary) in the Regional Physics Department of the Western Regional Hospital Board, Glasgow.

J. B. Dunne has been appointed a Research Engineer at Smiths Aircraft Instruments, Bishops Cleeve, Glos.

W. B. Gilboy has taken an appointment as Scientific Officer at the Atomic Energy Research Establishment, Aldermaston.

D. V. Harris is now Systems Engineer with R.C.A. Service Company, Riverton, New Jersey, U.S.A.

P. H. Harris has been appointed Technical Officer at the British Nylon Spinners Ltd., Pontypool.

J. S. Hill has been appointed Scientific Officer in the Control Mechanism and Electronics Division of the National Physical Laboratory, Teddington.

W. J. Ince is now Transistor Circuit Engineer with the Raytheon Manufacturing Company of Maynard, Massachusetts, U.S.A.

B. J. Jackson has been appointed an Assistant Lecturer at The College, Swindon.

J. C. Kelly is now Scientific Officer in the Metallurgy Division of the Atomic Energy Research Establishment, Harwell.

C. S. Metcalfe has been appointed Flight Trials Engineer with De Havilland Propellers Ltd.

A. A. Nicol is now a Research Fellow in the Mechanical Engineering Department of the University College of Swansea.

C. N. Owston has taken an appointment as Assistant Lecturer at Peterborough Technical College.

A. J. Tavendale has been appointed a Research Physicist in the Physics Department of the University of Tasmania.

N. K. Whitehead is now Installation Engineer at Marconi's Wireless Telegraph Company, Chelmsford, Essex.

Reviews of Books

SOLID STATE PHYSICS

By A. J. Dekker

London : Macmillan & Co. Ltd. Pp. xiv + 540. Price 45s.

There are several very good books on solid state physics. The subject is of interest both from the theoretical and the practical points of view. It has provided a field for the successful application of quantum mechanics and its growth has been parallel with the development of modern physics. The band theory of solids and the study of defects in crystals have provided a basis for the understanding of the important properties of metals, alloys and semiconductors. As well as to physicists, the theory of solids is becoming of increasing importance to metallurgists on the one hand and electrical engineers on the other. The design, manufacture and use of transistors demands more than a rudimentary knowledge of the theory of semiconductors. A large proportion of students, entering industrial research establishments on leaving the university, find themselves working on problems which come under the general heading of solid state physics. Since it is not possible to cover the whole or even most of the ground in a degree course, it is necessary that a textbook should cater both for undergraduates and for those who continue their reading of the subject after graduating.

This book by Professor Dekker satisfies these requirements. It may be read by anyone with an elementary knowledge of atomic physics and wave mechanics. The arrangement is such that the first part of the book requires no wave mechanics, the atomic, as distinct from the electronic, properties being discussed first. The first few chapters deal with the crystalline state, the theory of specific heats, alloys, lattice energy of ionic crystals, optical properties of insulators, ionic conductivity and ferro-electrics. The free electron theory of metals is first treated in Chapter 9. This is followed by chapters on the band theory of solids, the theory of conductivity, semiconductors and transistors. There are chapters on electron emission from surfaces and on magnetism, and there is a brief appendix on some topics in thermodynamics wave mechanics and statistical mechanics. Adequate references to original papers and to other books are given so that a student studying the subject seriously for the first time will very soon find his way about.

The problems at the ends of the chapters are an interesting feature of the book. Many of them are

certainly of the non-trivial kind and they include material which in some books would form part of the text. They are not of the kind that can be done in half an hour and often they require a study of original papers. Problem 11, Chapter 9, for example, asks for the theory of field emission through a triangular potential barrier. To answer this would mean consulting the well known paper by Fowler and Nordheim. All this is very good. The reader would gain much by studying the subject in this way. The book is well worth buying and well worth reading.

M. R. HOPKINS.

TEACHING MATHEMATICS IN SECONDARY SCHOOLS

Ministry of Education Pamphlet 36

H.M.S.O. Pp. viii + 154. Price 6s.

All teachers of mathematics are indebted to the excellent reports which the Mathematical Association publishes from time to time; they contain a wealth of information on teaching methods which have been tried and tested in the classroom. Official publications on Secondary School Mathematics appear less often; the present pamphlet is the first since *Senior School Mathematics* was issued in 1934, following a more general report in 1912. It should be said immediately that this is an outstanding document, enshrining much good practice and useful information, and it will be welcomed generally. It should contribute significantly to the better teaching of mathematics.

No reader will feel expert on all the matters with which it deals, for it covers the whole range of secondary modern and grammar school mathematics, and in a chapter headed "The First Stages" comments wisely on mathematics in the Primary School. The specialist, however, who dips in at one particular chapter is likely to be attracted into reading the whole pamphlet. He is also likely to relish many of the quotations: "Sir Arthur Eddington once said 'Progress is measured not so much by the problems we are able to solve as by the questions we are enabled to ask.' A class which does not ask questions is in the wrong hands." Again, "Professor J. L. Synge has said that the use of Applied Mathematics in its relation to a physical problem involves three stages: '(i) A dive from the world of reality into the world of Mathematics; (ii) a swim in the world of Mathematics; (iii) a climb from the world of Mathematics back into the world of reality, carrying a prediction in our teeth.' And in varying degrees this is true of the Mathematics encountered in any type of Secondary School."—to which one might add "any University or Technical College," and comment that such an outlook on the part of teachers might transform the teaching of mathematics and physics, and solve some of the problems associated with the teaching of scientific method.

Of all school mathematics, perhaps it is in the teaching of geometry that there have been the most profound changes. "The road from unadulterated Euclid has been long and arduous," and we are all indebted to the pioneers in the Association for the Improvement of Geometrical Teaching, whose efforts are rightly recognized in this pamphlet. In 1909, Circular 711 of the Board of Education could complain "the majority of teachers have not sufficiently availed themselves of the opportunity of breaking away from the bad parts of the Euclidean tradition; on the other hand a few have gone to an extreme in thinking that practical work is everything, and have sacrificed the training in rigid deduction which is an essential element in school geometry." To-day the teaching of the subject has been greatly influenced by the Mathematical Association Report of 1923, which suggested a division of the work into three groups: A, the Experimental Stage, B, the Deductive Stage and C, the Systematizing Stage. "The purpose of Stage C is to review the knowledge gained and to build it into a coherent system of logical sequences based on a comparatively small number of axioms." One welcomes the emphasis on discovery and intuition in the earlier stages, but regrets that Stage C tends to be overlooked. It seems right to stress that "To discuss what is meant by proof is, of course, very necessary in the Sixth Form. Many reasons which might satisfy a pupil lower down in the school should not satisfy him at this stage. He must see that the certainty of Mathematics is not that of its conclusions but is the certainty that the conclusions follow from the premisses, given the rules of reasoning." And again "A rigorous proof is a chain of argument to which no one could object who accepts the rules by which we proceed from one or more statements to another; the conclusion must be accepted if the premisses are accepted."

There is a final chapter on the history of mathematics and its bearing on teaching. "As was said at the beginning of this pamphlet, the present position of the teaching of Mathematics can only be understood against a background of history; it may be said with equal truth that Mathematics can be properly taught only against a background of its own history."

One could wish that this pamphlet were compulsory reading for all teachers of mathematics and physics.

J. TOPPING.

ORDINARY DIFFERENTIAL EQUATIONS

By Wilfred Kaplan

Massachusetts: Adison-Wesley Publishing Co. Inc. Pp. xv + 534. Price $8.50.

It would be unfortunate if this were regarded as just another book about differential equations, for in it the author has made a noteworthy and interesting effort to remove the veil of mystery which all too often surrounds this subject. He is at great pains to explain to the reader the underlying significance of a differential equation and what we are really doing when we carry out the process of solution. This he does, first of all, by discussing what information can be deduced from the equation itself, prior to solution. He then introduces the idea of the solution of a differential equation through very simple graphical and numerical step-by-step methods. The reader is led to regard the process of solution as a sort of generalized process of integration, and at the end of the first chapter he knows that, in principle at least, he can solve any differential equation to any desired accuracy by stepwise integration. The

author then reveals that for certain differential equations, which arise frequently, special methods are available for finding solutions in explicit form. Thus the reader comes to look upon the standard methods of solution as useful tricks of the trade for carrying out the process of solution and sees them in their right perspective because the significance of the process has already been explained to him. Later the author develops the idea that a differential equation is sometimes a relationship between an input function and an output or response function for a given physical system. This is an approach which is likely to be helpful to engineers concerned with instrumentation and control.

The rest of the book deals with all the familiar analytical techniques for solving ordinary differential equations. Numerical methods, and digital and analogue machines receive only passing mention. Existence and uniqueness theorems are very sensibly reserved for the last chapter. An attractive feature from the teaching point of view is the large number of examples for the reader to attempt, and answers are given. According to the author, the book contains enough material for a year's course. In the reviewer's opinion, most students will find enough to occupy them for three years unless they are to study differential equations exclusively.

J. Crank.

QUANTUM PARTICLE DYNAMICS

By James McConnell

Amsterdam : North Holland Publishing Company. Pp. xi + 252. Price 40s.

This is an attractive book. The subject matter is of central importance in physics, it is presented with clarity and elegance and at a level which will make the book useful to a large class of readers. It should be helpful to honours degree students in physics and also to those whose research involves the study of elementary particles. Although the reader is not required to have any previous knowledge of relativity theory or quantum mechanics, he is not allowed to remain in this unsophisticated state for long. The amount of mathematical knowledge presupposed is well within the reach of an undergraduate.

The first chapter deals with the special theory of relativity and the second is an introduction to quantum theory. The Schrödinger equation is set up after discussing de Broglie waves, and the theory of the hydrogen atom is given, followed by a discussion of quantum mechanical operators. There are chapters on Heisenberg's matrix mechanics, angular momentum and spin and on systems of particles. Chapter VII is on the Dirac equation and the following chapters include those on the quantization of the electromagnetic field, the photoelectric and Compton effects, brehmstrahlung and electron pair production, nuclear forces and mesons, and nucleons.

The student will find this book useful because it is concise and yet without severe condensation of the mathematical reasoning that is essential to the subject. A study of it will reward him with both the ability and the anxiety to read further.

M. R. Hopkins.

PRINCIPALS OF ELECTRONICS

By M. R. Gavin and J. E. Houldin

London : The English Universities Press Ltd. Pp. xii + 348. Price 30s.

There are already so many textbooks of electronics that one might expect by now a space-charge effect to be discouraging further emission. So far, however, there seems to be no indication that conditions are other than inspiration-limited and books on this subject continue to be emitted with remarkably little shot-noise ! This latest edition to the Physical Science Texts series neither is, nor claims to be, strikingly original or ambitious. Indeed, at first glance there seems to be little to distinguish it from many of the existing books on electronics.

It is a general introduction to the subject, suitable for a first degree course, and covers the behaviour of free electrons and of electrons in matter, the characteristics of valves and transistors, and the use of electron devices in amplifiers, oscillators, rectifiers, switches, etc. (but without dealing in detail with specific applications). The emphasis throughout is on physical principles and there is, it is pleasing to note, little or no " circuitry " or constructional detail of the kind that so often obscures the fundamentals of this subject. (This is not to suggest that such topics are not important : but they are best dealt with when the basic principles have been assimilated.) The book is well illustrated and the algebraic notation used distinguishes clearly between the different components of current and voltage that exist in electronic devices. Of particular interest is the well-chosen collection of numerical and other examples—mostly taken from Institute of Physics and Institution of Electrical Engineers examination papers.

But, within its limited scope, this book is remarkably successful and presents, in the reviewer's opinion, just that kind of account of electronics that is required for a general introduction. Its keynote is competence and clarity and it can be strongly recommended to all students.

A. E. De Barr.

PRINCIPLES OF MODERN PHYSICS

By Robert B. Leighton

London : McGraw-Hill Publishing Co. Ltd. Pp. xii + 795. Price 97s.

This book has grown out of a lecture course given to final year undergraduate and first year students at the California Institute of Technology. In spite of the fact that a book invariably exceeds the lecture material it is based on, this one gives a fair idea of what a student of physics in one of America's best institutions of higher education is expected to know in the way of modern physics. As such it ought to be an eye opener to anyone in this country who still believes that American higher education is not very good. These students are physicists, but they are expected to know before they start on this course " Classical mechanics, through Lagrange's equations, and rigid body dynamics, including the tensor of inertia, electromagnetism through Maxwell's equations, including the radiation from an oscillating electric dipole and preferably oscillating cavities, and mathema-

tics through ordinary differential equations (including power-series solutions), some partial differential equations (including separation of variables), orthogonal functions, vector analysis and some tensor analysis." How many English physics students know all this when they start on their final undergraduate year ? And how many of them a year later will have a working knowledge of the special theory of relativity, quantum mechanics, quantum statistics and nuclear physics, which are the subjects covered in this course ? Furthermore the book is no easy reading for, like many of the more advanced American textbooks, it expects the student to do a great deal of the work himself. The American student is used to this, but his English counterpart expects textbooks to do the work for him. The reason for this different approach lies almost certainly in the different types of examination. The American needs only to have the fundamentals of his subject at his fingertips, the Englishman must have a thorough knowledge of every detail, while his lack of knowledge of fundamentals often escapes detection. I have no doubt as to which method makes the better physicist.

Unfortunately it must now be admitted that even from the American point of view this is not a good textbook. In range it covers what is usually done in three or four books, but instead of cutting down on depth, the author gives us a little of everything and cuts down on explanations to a quite indefensible extent. For example, we are presented with seven different nuclear models, but nowhere is there any indication why a nucleus can apparently be all things to all men. There is a vast number of examples scattered throughout the book, many of which give excellent practice and a clearer understanding of the subject, but a fair proportion ask for the derivation of very important results, such as for instance the number of energy eigenstates per unit volume of phase space for a free particle. There is no hint of a method of solution, merely the answer, and the result is of course required several times later on. Mathematics is put between the physics wherever it may be needed so that half way through the discussion of spin—where we are incidentally expected to know what matrices are—we are given the rules for matrix multiplication and half-way through the treatment of the hydrogen atom the associated Laguerre polynomial is derived—inadequately—from the ordinary Laguerre polynomial, which the student is apparently expected to know.

The book covers such a wide range that it would be churlish to complain about inadequacies and minor errors in one's own speciality, which certainly exist, although one might point out with justification that there is no need to write a book of such width. Much better books on the various topics covered exist and the student should go to these. Once he has mastered the "principles of modern physics" he will find this book useful in getting practice in the principles, and his teacher too will find a discriminating perusal well worth while. The examples will keep his tutorials going for years.

The book uses the MKSA system of units and this reviewer, who has until now always used the c.g.s. system, reports with pleasure that he accomplished the switch over without so much as a thought.

L. R. B. Elton.

PHYSICAL LAWS AND EFFECTS

By C. F. Hix, Jr., and R. P. Alley

New York : John Wiley & Sons, Inc.; London: Chapman & Hall Ltd. Pp. 291. Price 64s.

The deliberately cryptic descriptions given in this book, one of a series written by (American) General Electric authors, are intended as a quick reference source for engineers and scientists, and the value of this useful compilation is enhanced by its being indexed alphabetically by names, physical quantities involved, and fields of science. In the opening chapter Mr. Hix suggests various ways in which the book can be used as " a practical part of the engineering approach to problems." He says that " the authors are continuing to build their compilation, for this text is by no means complete, nor is it intended to be." The description of the items is followed by illustrations of their uses, a reference to their magnitude, references to the literature, and the quantities that might be measured by its use.

Although rather expensive for any individual scientist or engineer in this country, it should certainly be available in research and development laboratories.

H. R. Lang.

THE SERVICES TEXTBOOK OF RADIO VOLUME 5

By E. V. D. Glazier and H. R. L. Lamont

London : Her Majesty's Stationery Office. Pp. xi + 500. Price 25s.

This book is one of a series of seven volumes designed to cover all aspects of radio and telecommunications including radar. It is planned to meet three standards of readers, the beginner, the technician and the more advanced student. There are marked paragraphs which the beginner can leave out without losing continuity and the more detailed mathematical analysis is reserved for appendices at the end of each chapter. Even these need not tax the student unduly : Maxwell's equations are given in the full Cartesian form. Rationalized m.k.s. units are used and the authors have used the well-established *kappa* for permittivity instead of the incomprehensible but fast gaining *epsilon*.

The main topics covered are transmission lines, wave guides and cavity resonators and aerials. As might be expected, the authors, Drs. Glazier and Lamont have given a very lucid and well illustrated treatment. The microwave section will be useful to physicists and others who find their interest moving towards this region. Some may wish that backward wave oscillators and ferrite isolators had been given some space but in this rapidly expanding field some things must be left over.

Any criticism must be of a minor nature. In the text of chapter 1 the symbols *a*, *b* and *d* are not explained until the appendix. In chapter 2, *a* and *b* are used again for the power factors of the series and shunt elements.

The diagrams and illustrations are clear and the whole layout, edited by the Technical Staff of *Wireless World* deserves great credit. As a communication textbook this is very good value.

S. N. Ray.

The Institute's Journals

PRINCIPAL CONTENTS OF THE JUNE, 1959, ISSUES

Journal of Scientific Instruments : Volume 36, No. 6

Temperature controller based on measurement of rate-of-change of temperature. By A. B. Cairnie and J. D. Pullar.

The rate-of-change of temperature of water circulated from a 120 gal tank round the jackets of a direct calorimeter was required never to exceed 0·0005° C/min. Measurement of the rate-of-change of temperature was provided by a gradient layer surrounding a metal block in the tank. A controller was designed to maintain the instantaneous rate-of-change of temperature below 0·0002° C/min, except for a negligible fraction of the time. The mean rate-of-change of temperature is so low that temperture stability to within ±0·1° C has been obtained for a fortnight. A temperature-controlled room and constant voltage transformer are not required.

The epitasimeter : An instrument for process control by means of the continuous measurement of surface tension. By W. H. Aarts.

Physical methods of determining chemical concentrations are very useful in the control of process plants. While many physical properties have been so used, little use seems to have been made of surface tension.

Surface tension measurements are frequently used in the laboratory, and generally an absolute value of the surface tension is required. For process control, however, absolute measurements are often not essential. The method described here uses a jet of liquid issuing from an elliptical orifice to form a standing wave. Viscosity effects are either eliminated or allowed for in the temperature compensating circuits.

Apparatus for measuring the spreading coefficient of a liquid on a solid surface. By J. F. Padday.

The apparatus described provides a direct-reading instrument for the measurement of the spreading coefficient of a liquid on a solid surface. The determination is based on the measurement of the maximum height of a sessile drop of the liquid-solid system.

Homodyne detector for reproduction of periodic wave forms. By C. Lagercrantz.

The principle of homodyne detection is applied to a method of reproducing periodic wave forms in the audio-frequency range on a pen recorder. The signal is fed to a gate, which is opened by a short reference impulse. The time position of the reference is swept over the signal cycle by aid of a linear phase-shifter, so that all points on the signal curve are consecutively and individually recorded when passed through the gate to an r.c.-filter and finally to the recorder.

Measurement of equivalent noise resistance of a noise thermometer amplifier. By H. Pursey and E. C. Pyatt.

A method is described for the measurement of amplifier noise to an accuracy of better than 1%. The method involves the determination of the ratio of noise due to the amplifier alone, and the noise due to the amplifier and a wire-wound resistance at a standard temperature. Random errors are analyzed, and the effects of systematic errors are discussed.

The work described in this paper forms the first stage in the development of a "Noise Thermometer" for absolute measurement of temperature.

Double-beam infra-red grating spectrometer. By J. L. Hales.

An infra-red foreprism-grating spectrometer of compact design is described. Non-precision components are used in the instrument which nevertheless has a high performance. Two 2400 lines/in. gratings are used in the first order to cover the wavelength range 2 to 17 μ. A ratio-recording double-beam system is employed.

Improved polythene-shielded net radiometer. By J. P. Funk.

An improved net radiometer using very thin hemispherical polythene windshields is described. Balanced radiant heating of the windshield prevents formation of dew. Two of these instruments, suitably matched, permit direct measurements of radiative flux divergence in the lowest few metres of the atmosphere, with an accuracy of at least 10%. Some preliminary results are given.

Instrument for measuring liquid flows less than a millilitre per hour. By J. R. Pilbrow.

Flow is channelled through a narrow passage containing thermojunctions placed before and after a heated wire. The differential e.m.f. is proportional to the flow when this is small, up to 150 μV for 5 ml.h^{-1} in the existing instrument. Suitably large collectors buried in porpous material can channel seepage into the instrument. Flows of 0·005 ml.cm^{-2}h^{-1} (to 20%) have been measured in this way in a river bed.

Resistance thermometer spear for field measurement. By A. C. Jason and A. Lees.

The instrument described measures temperatures in the range −30° to +70°F with an accuracy of ±0·2°F. The sensitive portion consists of a copper wire spiral enclosed in a length of hypodermic tubing; the resistance is measured on a Wheatstone bridge. The instrument is cheap, reliable, robust and self-contained.

Vacuum fatigue apparatus. By N. J. Wadsworth.

An apparatus is described in which it is possible to anneal specimens in vacuo and then fatigue them in vacuo or in any desired atmosphere without intermediate exposure to air. Annealing temperatures of up to 800°C are used and extension up to 1000°C is possible. The specimens are flat sheets. An electromagnetic drive is used to fatigue them in reversed bending between constant strain limits at 100 c/s. Both extremes of the movement of the specimens are monitored optically and a servo system keeps them constant in spite of changes in the modulus or damping of the specimens during the test. An automatic cut-out stops the test as soon as a large crack appears in the specimen. Some typical results are shown.

Demountable vacuum seal for operation at temperatures from −188°C to 800°C. By R. Brymner, A.Inst.P., and W. Steckelmacher.

A new type of metal gasket vacuum seal is described which depends on a surface-friction effect instead of compression, which is the basis of most seals described so far. Tests have proved the effectiveness of the seal for repeated cycling between −188 and 800°C on flanges of 3 and 5 in. diameter and on a ½ in. vacuum union. The materials used include mild steel or stainless-steel flanges with flat gasket sheets of soft copper, iron, stainless steel or nickel. Other metal gasket vacuum seals are briefly reviewed and the mechanism of sealing is discussed. A table of recommended dimensions for flanges from 3 to 12 in. diameter is also presented.

Strobometric method of measuring the phase angles of very low currents. By S. B. Girvan and D. S. McIlhagger.

A simple device is described by means of which the phase angle of mains-frequency currents may be measured, with respect to the applied voltage, to an accuracy of ±0·5°. The method was used with currents in the range 0·01 to 10·0 μA but it is not restricted to this range.

Bakeable vacuum seals using aluminium-wire gaskets. By J. Holden, L. Holland and L. Laurenson.

The use of aluminium wire as a vacuum seal between steel flanges has been studied. Gaskets made by twisting together the ends of a 22 s.w.g. wire could be baked to 200°C before they leaked on cooling. High temperature working was possible with butt-welded loops of aluminium wire providing the gasket was highly compressed. Such seals did not cold

weld but, at baking temperatures above 400°C, the aluminium plastically flowed and adhered to the mating flanges. The " cemented " joint was vacuum tight at low and high temperatures (20–550°C) although the securing bolts became loose after baking. Such a seal leaked only when the aluminium reached its melting point. Information is given on the minimum compression force which must be applied to an aluminium wire in order to form a cemented joint at elevated temperature. Several uses of the aluminium-wire seal are described.

Measurement of low values of internal friction at elevated temperatures. By P. D. Southgate.

Some features are described of an apparatus which measures internal friction of longitudinally resonant specimens at elevated temperatures. The apparatus uses electrostatic drive and frequency-modulation detection, and operates near 100 kc/s, at temperatures up to 1300°C. Limits of operation are discussed, and a comparison made of the observed amplitude-dependent loss at the specimen supports with a simple theory of frictional loss.

British Journal of Applied Physics : Volume 10, No. 6

CONFERENCE REPORT: Summarized proceedings of a conference on nuclear fuel cycles–London, Jan. 1959

A conference on nuclear fuel cycles, organized by The Institute of Physics in collaboration with the British Nuclear Energy Conference, was held in London on January 22 and 23, 1959. The papers presented, and the discussion on them, are summarized in this report. A full proceedings will appear in the *Journal of the British Nuclear Energy Conference* for July.

ORIGINAL CONTRIBUTIONS

Determination of the size of defects by the ultrasonic impulse echo method. By J. and H. Krautkramer.

Much to the detriment of ultrasonic testing and all attempts at standardization, it is not yet possible to compare the results from different kinds of equipment regarding the echo of a back wall or a small defect. In order to facilitate this, the relations between echo height, distance and size of circular disk defect are brought into simple and universally applicable forms. It is shown that the first back echo of a simple plate is the most convenient reference echo. With the help of a calibrated gain control as accessory to a usual flaw detector and a graphical representation of the formulae, an equivalent circular disk defect can be attributed to the actual defect. The influence of curved contact and back wall surfaces, and the application of the method for determining ultrasonic attenuation in thick specimens, is discussed.

Measurement of the tensile strength of brittle materials. By R. Berenbaum and I. Brodie, A.Inst.P.

Three alternative methods for measuring the tensile strengths of brittle materials are investigated and compared with the conventional pull method. These are a bending test, an indentation test and a test in which disks are compressed diametrally. Experiments on plaster of Paris, coal and cement show that, apart from the bending test, the methods give results in reasonable agreement. The bending test, however, is liable to give considerably different results, and it is shown that this can be attributed to its sensitivity to surface conditions.

Effect of sound intensity on dispersion and coagulation in ultrasonic emulsification. By R. S. Krishnan, F.Inst.P., V. S. Venkatasubramanian and E. S. Rajagopal.

The contributions of dispersion and coagulation to the process of emulsification can be determined by following the rate of emulsification, and this method is used to study the effect of sound intensity on them. After a certain threshold of intensity, below which no cavitation occurs, the dispersion increases with the sound intensity. The coagulation also increases with the sound energy, but with a residual coagulation even in the absence of the sound field. The nucleation phenomenon is also studied. All the results agree with the general theoretical considerations.

Temperature errors introduced by temperature-measuring probes. By I. G. Donaldson.

Calculations are made of the thermal disturbance produced in hot ground by the presence of probes that are thermally conducting. It is found that temperatures measured with metal probes with a length/radius ratio of up to 100 : 1 may be considerably in error. Wooden probes are, however, quite satisfactory. For measurements of high accuracy thermocouple wires alone, i.e. not enclosed in any supporting probe, are quite satisfactory although copper wires should be replaced by manganin if possible. The work has a bearing on surveys being made of the heat flow from the thermal regions of New Zealand.

Technique for preparing thin films of α-iron. By D. G. Brandon and J. Nutting.

A technique is described for preparing foils of α-iron which are suitable for direct-transmission examination in an electron microscope. While there is no guarantee that a particular point on the foil will be thin enough for examination, results show that the technique produces foils enabling localized effects to be observed.

Energy variation with pressure and temperature in a sonic stationary wave. By A. R. Ingles.

Using stationary waves in air, carbon dioxide and coal gas, the variations of the energy per wave per unit area E with pressure p at different temperatures have been plotted, and a relationship of the form $E = Kp^m$ obtained for a limited pressure range. The importance of correct impedance matching between the source and the surrounding gas is emphasized by the results.

Relationship between strength and porosity for coal compacts. By D. J. Millard, A.Inst.P.

When powdered coal is compacted by subjecting it to high pressures it is found that the quality of the compact as measured by strength tests is, for a given batch of powder, a single valued function of the porosity of the compact. The shape of this strength-porosity curve cannot be explained by treating the pores as if they only reduced the load bearing area available to withstand stresses in the compact.

The form of the observed strength-porosity curves for compacts tested at right angles to the direction of compaction has been explained in terms of the development of contacts between particles with increasing compaction, and of the changing action of pores as stress magnifiers. A strength-porosity relationship of the form $\sigma = (1 - \hat{p})\hat{p}^{-1}$ has been deduced, where $\hat{p}$ (" rationalized " porosity) is the ratio of the porosity of the compact to that of the pile of loose powder having no mechanical strength. It has been shown that this expression gives a good representation of the experimental data.

Measurement of high intensity stress pulses. By J. S. Buchanan, A.Inst.P., and H. J. James.

A modified form of the Hopkinson bar technique has been applied to the study of stress pulses produced in a simple explosive-metal system. The results are used to illustrate the kind of information which can be obtained from such an experiment. This includes measurements of the pressure in the detonation wave, the changing shape of the stress pulse induced in the metal and the normal fracture stress of the metal.

Absorption of sodium and argon by glass. By J. W. Wheeldon.

Methods are described for measuring the absorption of both sodium and argon by glasses. The rate of absorption of sodium increases rapidly with temperature and is linear with time at a constant temperature. Ionization of the sodium does not change the rate of absorption. Micro-sections show that the absorbed sodium forms a layer of apparently uniform sodium concentration which advances through the glass with a sharp front. The concentration of sodium in this layer was found to be as high as 2×10^{22} atoms cm^{-3} in one case. Argon is only absorbed when ionized and the rate of absorption is more or less independent of temperature below 300°C. The argon does not diffuse through the glass and is partially evolved when heated to over 350°C.

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